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## Designer's Guide to: Rotary switches

## Get the most from your programmable calculator

## Monochip contest winners design their own unique IC's

"CREATIVE DESIGN CONTEST" in this issue

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JANUARY 5, 1975
VOLUME 20, NUMBER 1

EDN

EXCLUSIVELY FOR DESIGNERS AND
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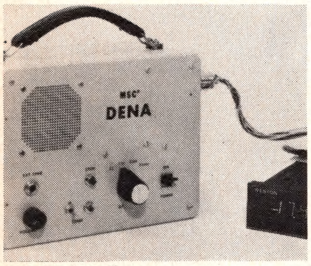

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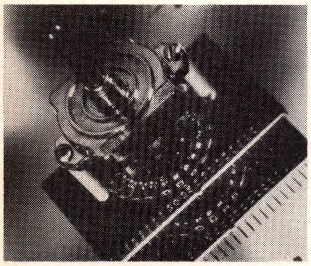

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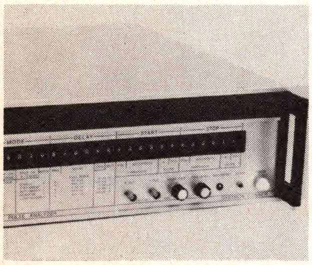

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## COVER

What you see is what you get — and how you get it. With Interdesign's Monochip, a designer can quickly and quite inexpensively translate his circuit into a custom IC. Art Director Dan Kicilinski created this cover from the winning entry in the Monochip contest. (See pg. 33.)

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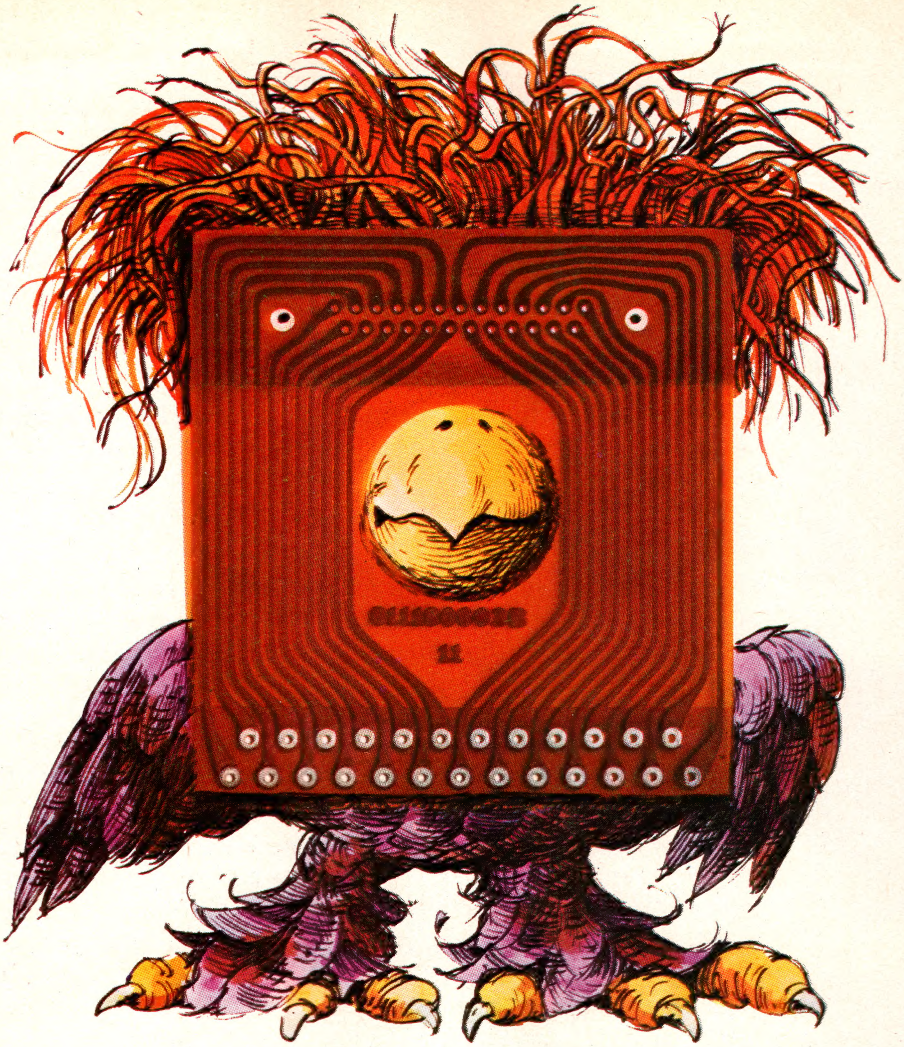

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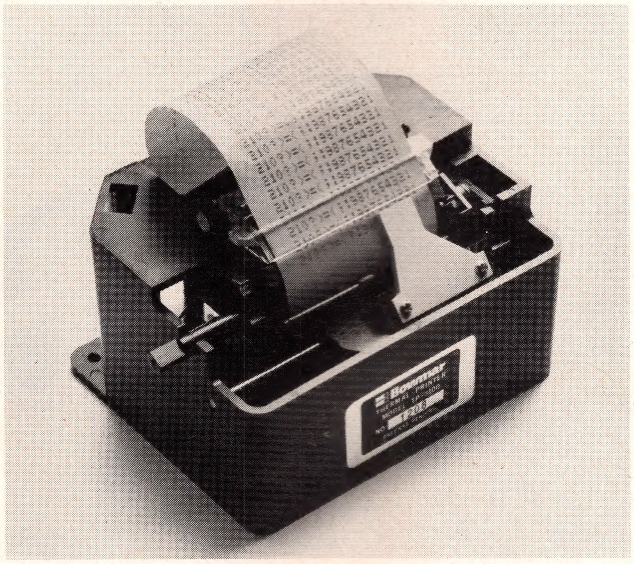

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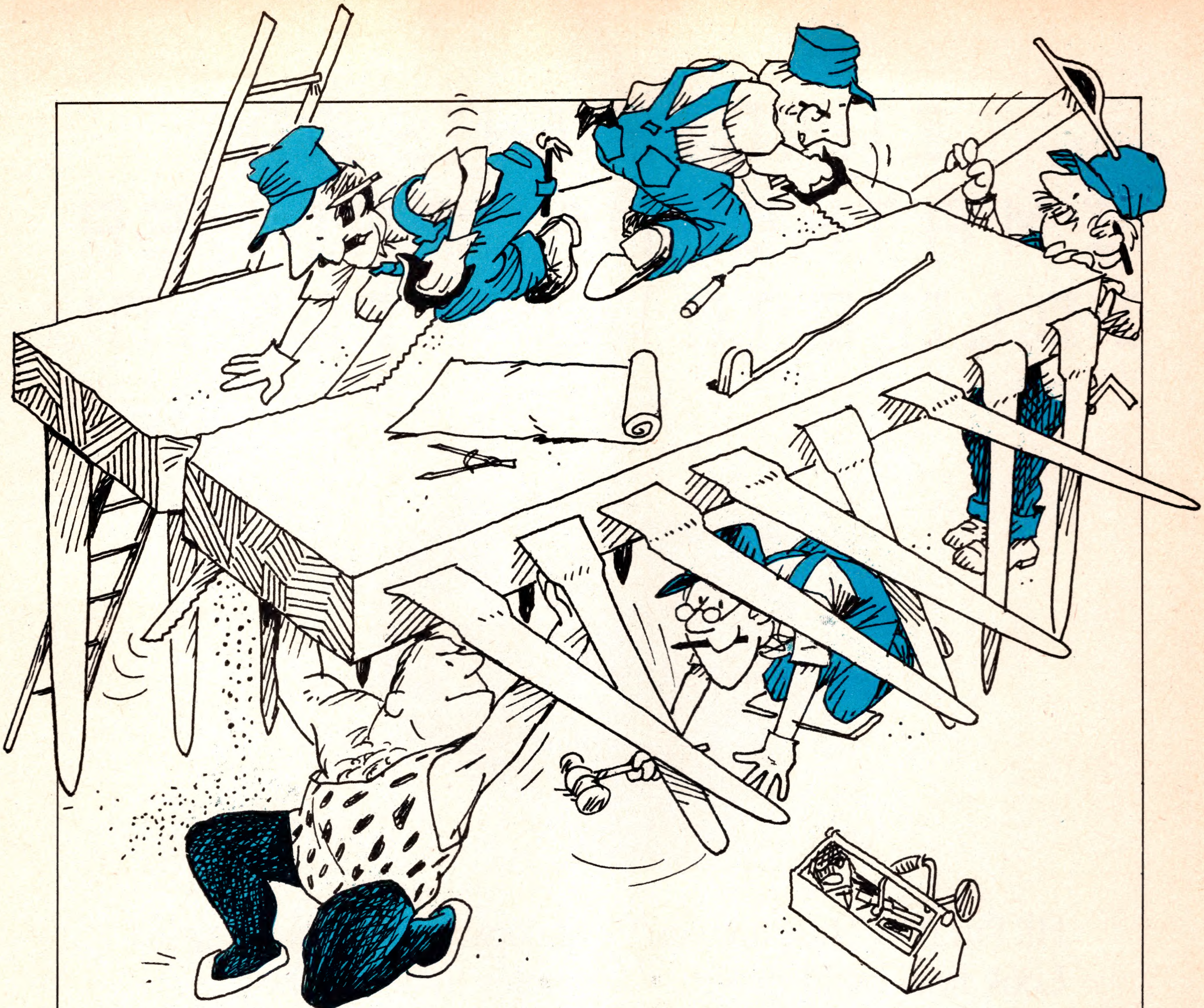

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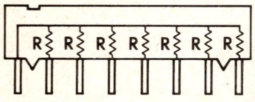

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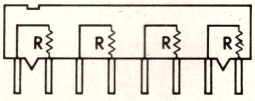

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# How's business?

That seems to be the popular question nowadays. The sorry state-of-the-economy is thrust upon us continuously through newspapers, radio and TV. This, coupled with layoffs and production cutbacks, has most of us wondering, "Just what are business prospects in 1975 and beyond?"

There's no question that the business cycle is in a downturn and that we are in a recession. Even our government has finally recognized that. But this shouldn't have surprised anyone, for our most leading indicators predicted the downturn as far back as 1971.

However, there is light at the end of the tunnel. These same leading indicators have already turned around and are on their way back up. How does that translate to business prospects in 1975?

Most companies in our business have experienced a dip—some more than others. And the low point is probably still a few months off. After that, recovery will be slow—taking until about mid-1976 to reach December 1973 peaks. All-in-all, 1975 should average about the same as 1974 with one difference—the best of the year will come in the last half as opposed to 1974 when the first half was best.

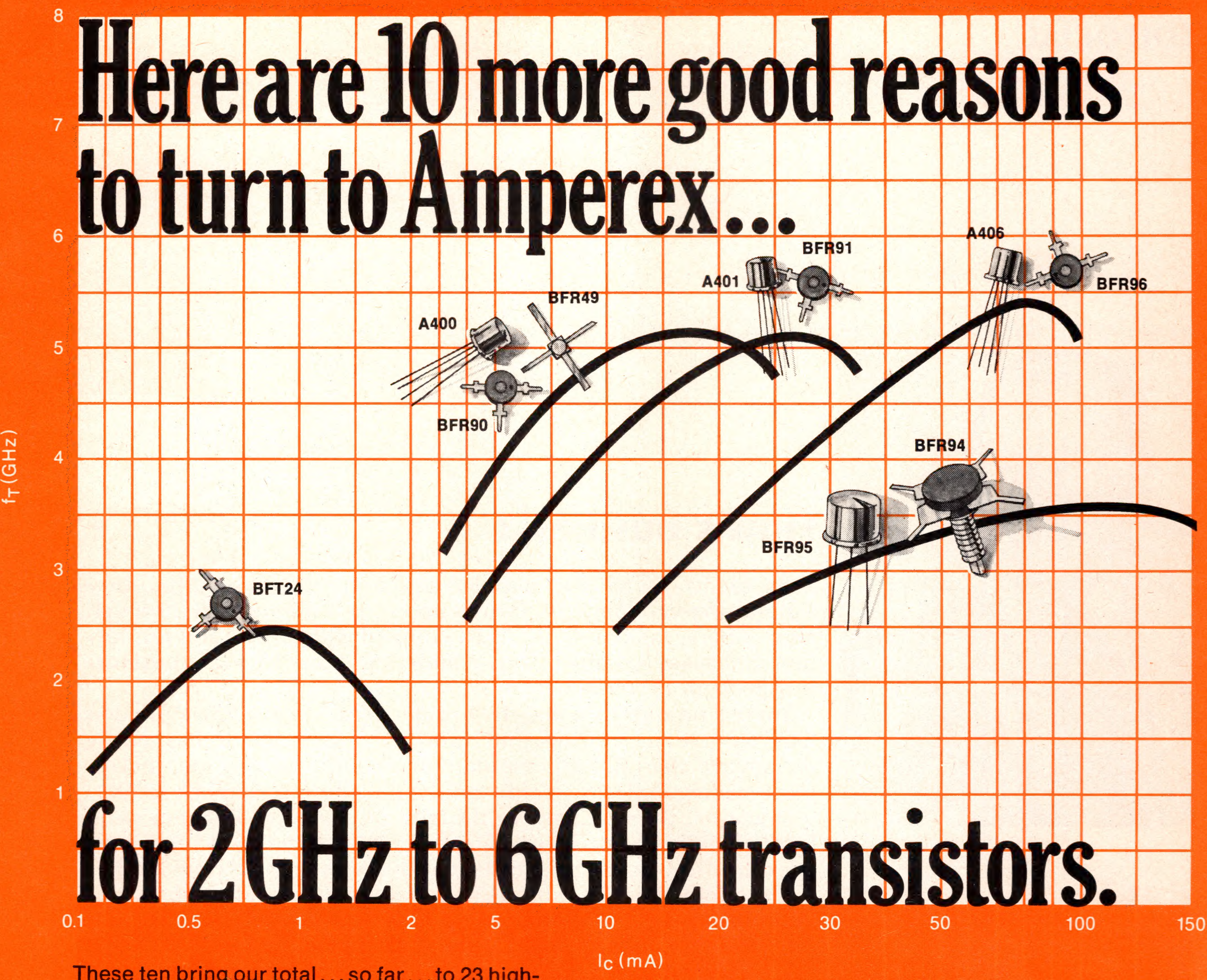
As designers, your tasks and design goals will change somewhat. With the oil embargo, people have become energy-conscious; and with high inflation they have become more cost conscious. Thus, demands on your designs will be such that they must last longer, be repaired more easily and must consume less power.

So how's business? Not great—not even good! How are prospects for 1975? Not great—but encouraging!

Roy W. Forsberg

**Editor**

# Here are 10 more good reasons to turn to Amperex... for 2GHz to 6GHz transistors.



These ten bring our total . . . so far . . . to 23 high-performance, small-signal RF transistors with gain-bandwidth products from 1 to 6 GHz . . . covering the operating current range from 100 $\mu$A to 150 mA. There's an Amperex GHz transistor to fill virtually any small-signal application up to 2 GHz . . . CATV/MATV amplifiers, portable pagers and transceivers, high bit-rate communications equipment, frequency counters and high frequency oscilloscopes, to name but a few.

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| A406 | TO-72 metal | 5.0 | 50 | $3.15 |
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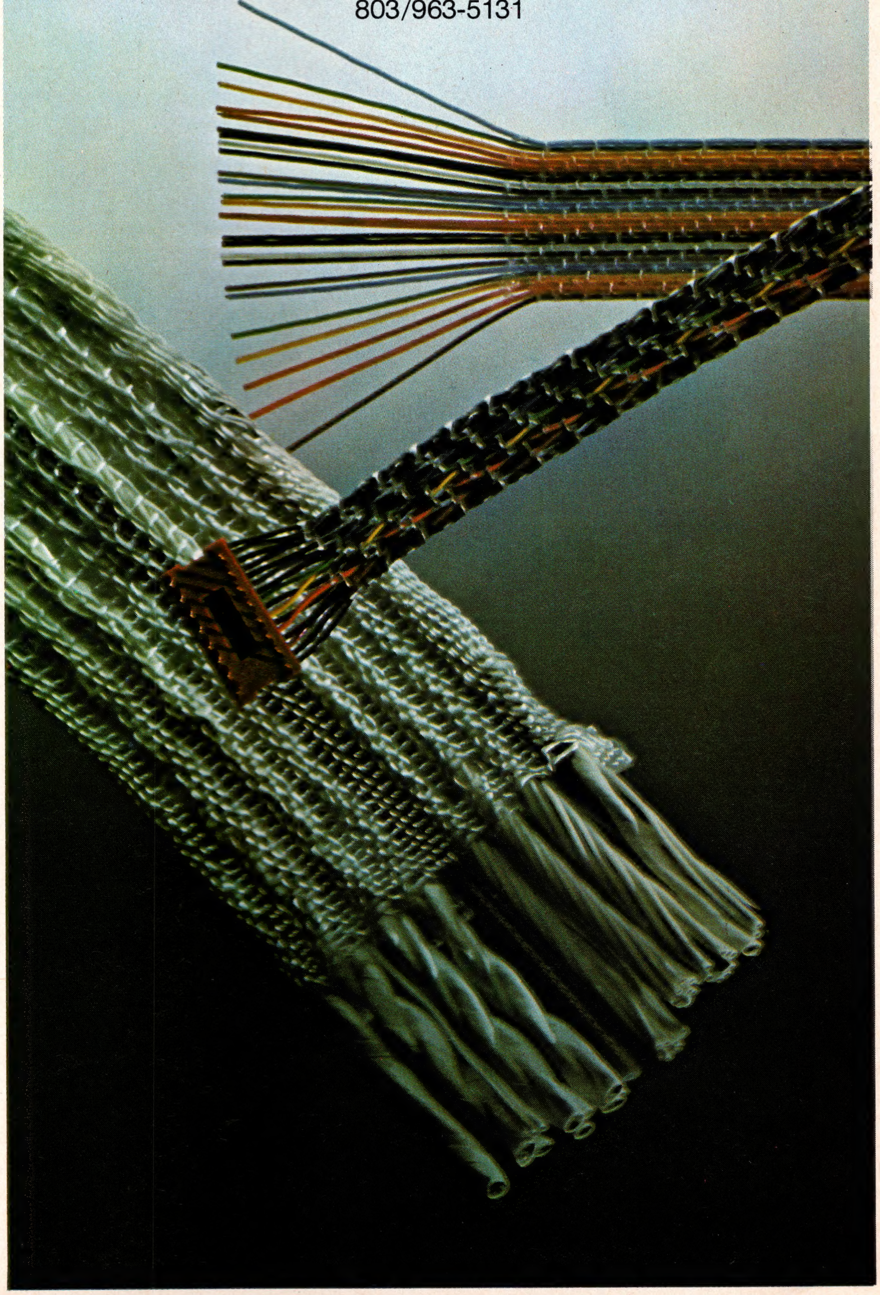

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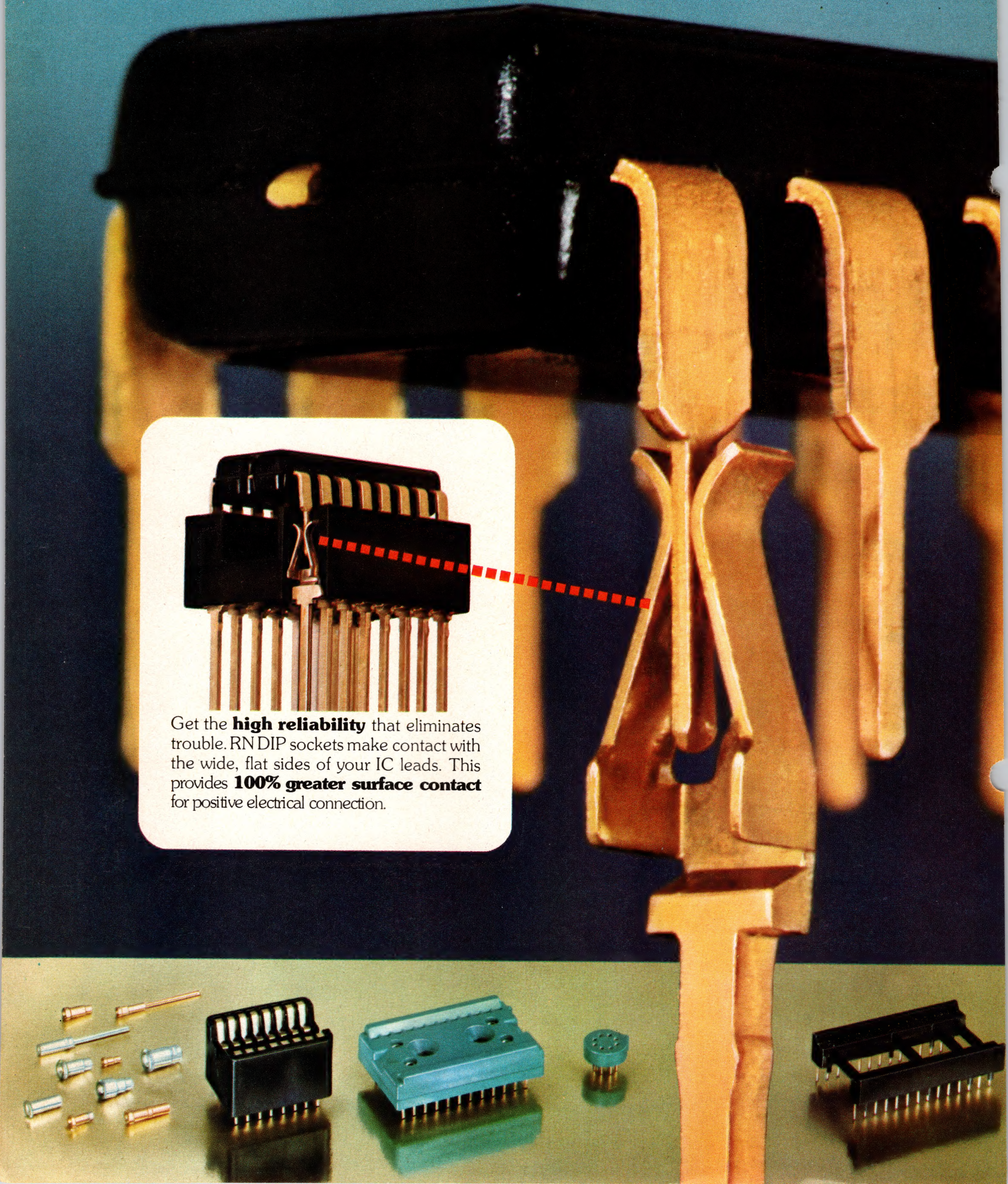

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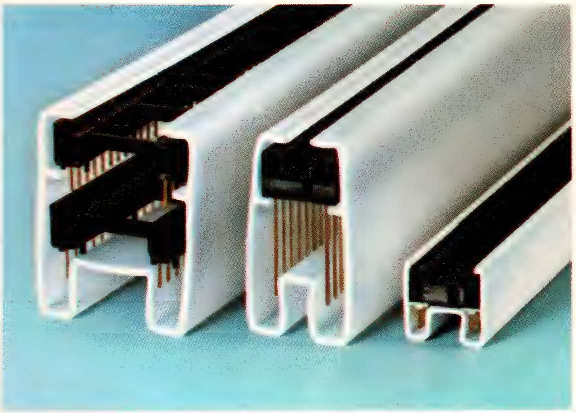

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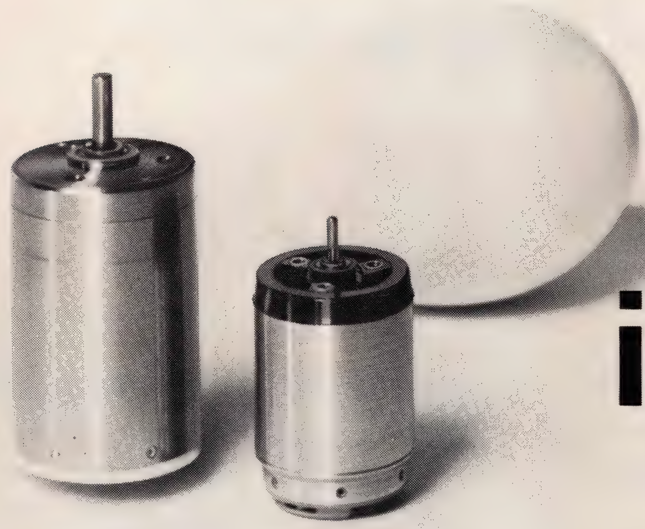

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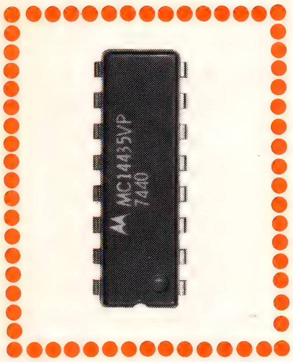

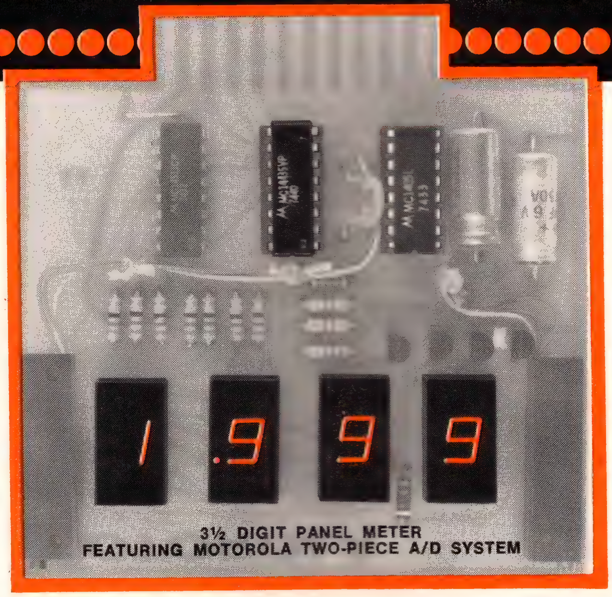

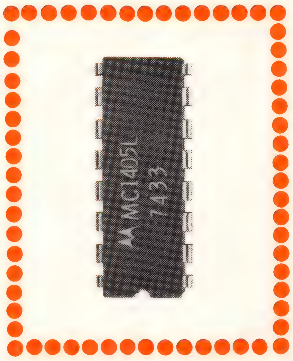

Introduction and availability of the MC14435 McMOS* low power CMOS A/D logic subsystem completes a Motorola team that should stay on top for a long, long run. Paired with the MC1405L analog dual ramp A/D subsystem, the MC14435 creates the greatest two-piece 3½ digit A/D converter system for panel meters and DVMs . . . and for equipment from bathroom scales to scuba gear. The MC14435VP is $11.31 in 100-999 quantities. Certainly modest.

The MC14435 is beautiful because of its low power dissipation, because it includes an on-chip clock, because it offers tremendous variety in selection of the single power supply, for a number of other reasons, but most of all because it interfaces directly in both directions. It interfaces directly with the linear subsystem at the input and directly with the CMOS, TTL or HTL at the output.

For its part, the MC1405 contributes no less. It too is a power miser, operates on a single power supply, and interfaces directly with the CMOS logic section. The linear subsystem includes an on-chip voltage reference, and it operates with outstanding accuracy. Its 100-999 price is $5.95. Also modest.

Together, the MC14435 and the MC1405L team up in a self-contained system which operates on a single supply of 5 to 15 volts, which includes internal voltage reference and system clock, with an input which needs no auto zero, which interfaces readout directly, which provides pin-out for over range indication, and which maintains the very best accuracy even with temperature variation. Not only that, it dissipates the least power, is simplest to build, and is the least expensive to buy, by far. The two-piece set is only $17.26 (100-999 pieces).

Technical information on this great new team is available from its creators. Write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, AZ 85036, or circle the reader service number if you prefer.

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# The digital "talkies" are coming—a new class of readouts

**Erwin Vodovoz,** West Coast Editor

An outgrowth of test equipment designed for the telephone companies has just been delivered to a blind engineer. Called DENA (Digital Electronic Number Announcer), this device converts an electrical BCD signal to a voice output **(Fig. 1)**. What makes the system unique is the quality of the voice output, and the techniques used to perform this feat.

## ROM's to the rescue

ROM's are the key to this system's high quality performance. Starting with a tape recording of a word, Master Specialties Co. of Costa Mesa, CA, performs an analysis and digitization using a computer. This results in a 64k-bit representation of the word. A proprietary process then reduces the size of the word to 16k bits. From that 16k-bit word, a paper tape is made that results in a ROM.

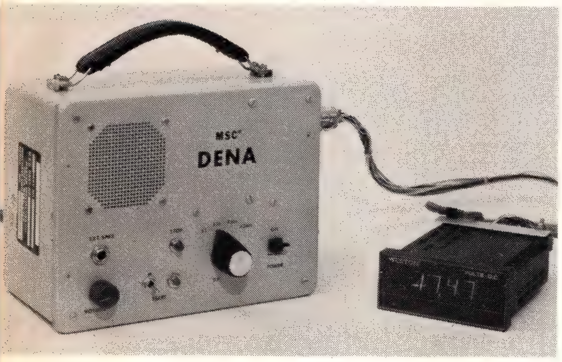

**Fig. 1—Talking voltmeter** is only one possible use of DENA. Other immediate applications of DENA's relatives include telephone test systems, radio paging systems, and verification of data entry.

The system's uniqueness lies in the fact that words are not formed by combining sounds, nor is a tape recorder used. Instead, a whole word is stored on one ROM. The resulting synthesized voice makes distinction from the original voice difficult.

Any word that can be spoken in half a second can be put into one ROM. Longer words require two ROM's. In DENA, 10 ROM's are used for zero through nine. Additionally, a tone that precedes the number indicates a negative value, while no tone exists for a positive one. Decimal points use a second tone an octave higher than the negative sign tone.

## Talk to me, machine

Putting it all together results in the configuration of **Fig. 2.** This first machine works with a 3-1/2-digit panel meter from Weston. DENA's front end logic accepts parallel BCD in an 8421 format, selects the proper ROM (word) serially, and inserts the decimal point where required.

Two operating modes are available. Continuous operation presents data in a rapid stream when it is received. In a second mode, DENA constantly updates its data, but "speaks" only on demand.

## Monitoring the transmitter

Intended use of the first DENA system is to monitor various operating parameters of a radio station. Mr. Paul Stebbins of Evanston, IL, a blind engineer, has been working with Master Specialties for three years to develop this system. Mr. Stebbins is now performing his initial

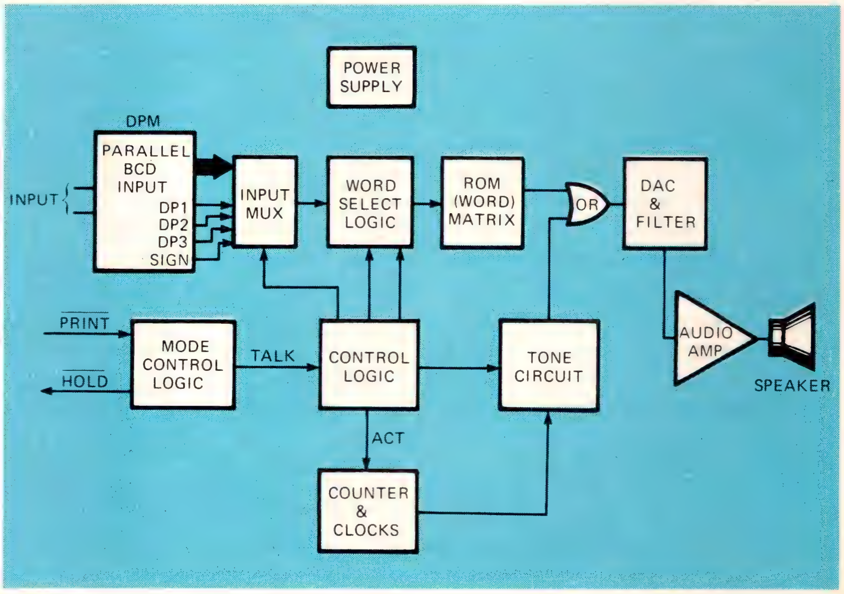

**Fig. 2—"Recording" of a whole word** on a single ROM chip is the key to DENA's impressive performance. As this block diagram shows, system is fairly simple.

test of DENA. Upon completion of the test, DENA will be mated with a Weston meter located in a panel with the function selector switches. Selecting the proper button will provide a "speak out" of plate voltage, plate current, screen grid voltage or antenna RF current.

Since, basically, DENA is a 3-1/2-digit, TTL-compatible machine that accepts a binary address, any instrument with such an output could be coupled to produce a voice output. For instance, in the future, Mr. Stebbins plans to couple DENA to additional devices such as a frequency counter or RF generator.

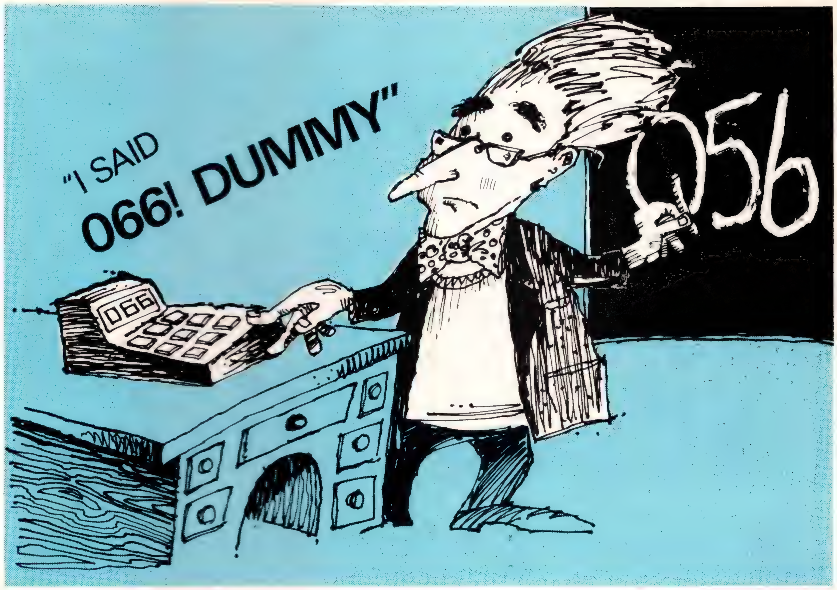

**Fig. 3—Digital readouts,** being hard to read in direct sunlight or under high ambient lighting, sometimes cause errors. But when the instrument **tells** you the reading, mistakes are minimized.

### The ultimate "readout"?

Not likely, but think about the possibilities. Ever worked on a pc board with closely spaced parts? You put the test probes on the desired test point. Then, when you look up at the DVM, you get a strange reading. Why? because when you looked up, your probes slipped off the test point or shorted out something. Another problem arises when you use a digital display in sunlight. It's often very difficult to read. A vocal output provides a convenient solution for these difficulties.

### A talking HP-35? Why not?

The next step in MSC's talking devices is a talking calculator, due to be completed in early 1975. The government will fund these calculators since they are interested in helping the blind with math, an especially difficult subject for the sightless. Eventually, MSC hopes to produce a machine comparable to the HP-35.

Human engineering is being performed to determine the best design for the blind. At present, it appears that a 20-key keyboard will be used. Each key will have several functions, so all the "scientific" computations can be performed.

The calculator will also require expansion of the ROM vocabulary. Words such as "log," "sine," "cosine," "positive," "negative" and "square" are needed. Since the generation of each word is an engineering task, it is expensive to increase the vocabulary. Therefore, new words are examined closely to see if a different one can be used, a word that would have multiple applications. When "positive" and "negative" are added to the vocabulary, they will be added to DENA.

Immediate applications exist for other members of these voice synthesizers. Automatic radio paging systems, aircraft warning systems, medical systems and data verification in communication systems are just a sample of the possibilities. ☐

# ISSCC '75 highlights semiconductor technology's global frontiers

A particularly topical program will be presented at the 1975 IEEE International Solid-State Circuits Conference, in Philadelphia, PA, February 12-14. Over 70 exclusive papers prepared by more than 170 authors from over 50 US/overseas companies, universities and government agencies will be highlighted.

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The meeting, to be held at the Marriott Motor Hotel, will discuss such timely subjects as LSI, optoelectronics, A/D-D/A techniques, active microwave diode circuits, microwave FET's, computer aids for IC design and testing, memory, high-speed and solid-state logic advance-

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ments, sampled-data analog signal processing, and analog circuit techniques.

Also featured are an invited session on technology frontiers; a keynote address by A. P. Speiser, director of research and development at Brown Boveri in Switzerland; and the annual ISSCC "best paper" award ceremony.

### ...and into the evening.

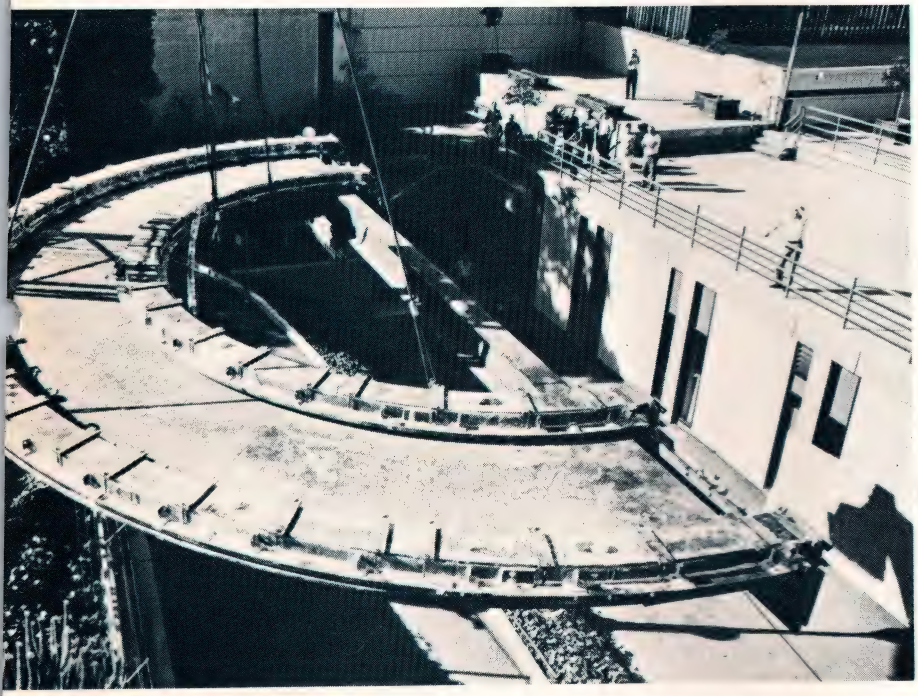
More than 65 panelists from the US, Europe and the Far East will participate in the ever-popular evening sessions. Covered will be such controversial areas as submicron technology, 4k RAM directions, logic implementation for custom vs. micro vs. macro designs, low-noise microwave devices and circuits, microprocessor architecture, CCD memories, LSI testing, data acquisition and conversion circuits, and oscillator/amplifier devices.

All registrants receive a copy of the annual conference report—the DIGEST of TECHNICAL PAPERS—a 280-pg. document with more than 500 illustrations. Edited condensations of all papers will be included, plus 25 day-evening session introductory overview statements.

Advance registration fees for IEEE members will be $35; nonmembers, $45. At-conference rates will be $40 and $50, respectively. Cutoff date for advance registration is February 7, 1975.

Programs with registration forms can be obtained from the Philadelphia Section IEEE office in the Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, PA 19174; or Lewis Winner, 152 W. 42nd St., New York, NY 10036.—*WP*

# World's largest magnet coil built for highest resolution spectrometer



**Over one-half mile** (8 tons) of special hollow extruded copper conductor comprises the giant magnet coil for 168-in. spectrometer presently under construction at Stanford University. This is the first of two coil sections built by Elma Engineering, Palo Alto, CA.

Stanford University's High Energy Physics Laboratory recently received the largest magnet coil ever built. Designed and produced by Elma Engineering of Palo Alto, CA, the coil forms an integral part of a 2000-ton spectrometer assembly presently under construction. When completed, scientists will use the assembly for basic research in elementary particle physics.

## Vacuum encapsulated

Building the 44-turn coil required slightly over one half of a mile (2685 ft., to be exact) or eight tons of copper conductor. The extruded 1.0×0.8-in. conductor features a 0.46-in. dia. cooling passage.

A prime requirement is that the coil be able to withstand high radiation environments, yet provide long maintenance-free operation. To achieve this, Elma developed a special technique and formulation for vacuum encapsulation.

## 20× better resolution

Within the next two years, installation of the entire 168-in. spectrometer should be completed. When operational, it will enable Stanford researchers to probe deeper than ever before possible into the structure of nuclear matter.

For instance, the spectrometer will provide angle measuring properties of 0.005°—about 20 times greater than existing machines. Similarly, its energy measuring resolution of 1 in 10,000 is better than present equipment by an order of magnitude.

Achieving this performance will require 3.5 MW of power plus 437 gal./min. of water to cool the giant coil's copper conductors.—*WP*

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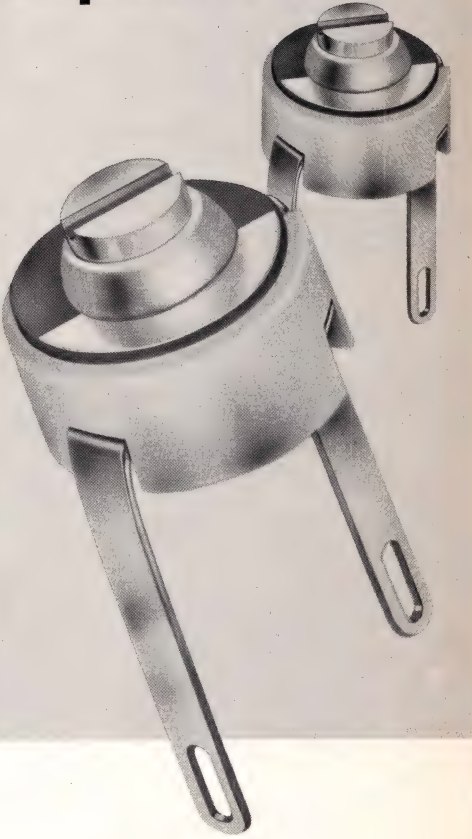

These ceramic trimmer capacitors are designed for broadband application, from audio to 500 MHz and afford an ideal *low cost* means of "trimming" circuitry such as crystal oscillators, CATV amplifiers and all varieties of communication and test equipment.

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**Electronic Design,** August 2, 1974

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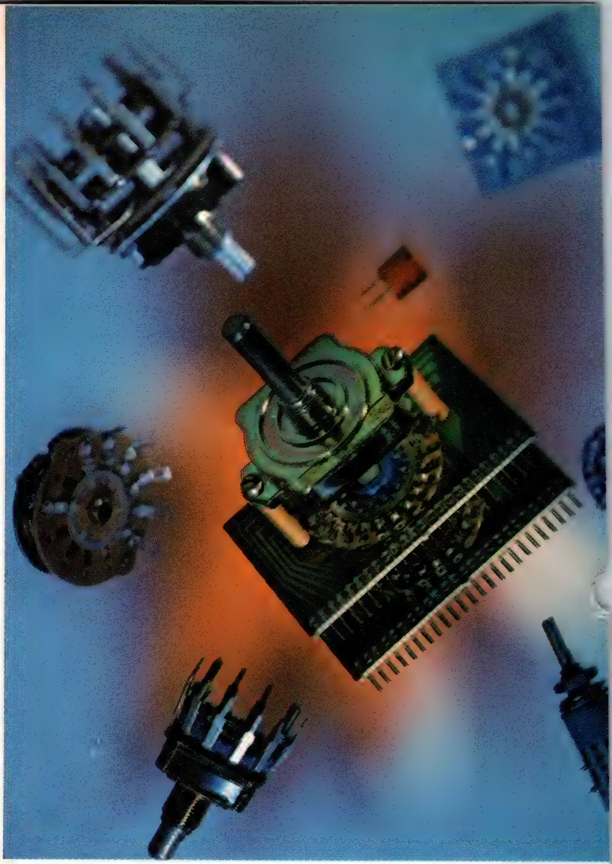


# Designer's Guide to: Rotary switches

*Recent developments in rotary switches pose two interesting questions: Is the switch part of the circuit board, or is it the other way around?*

**Bernard J. Golbeck,** Oak Industries Inc.

Rotary switches have been with us for a long time, but new versions are being developed that may have significant impact on pc-board and circuit designs of the future. The trend toward miniaturization, and the fact that some switching functions now can be handled by solid-state devices, are largely responsible.

A new approach, already in commercial practice, makes the switch stator and rotor become part of the circuit board itself—or has the switch mounted directly on the circuit board, which acts as its partial, or even sole, support. Already a number of options and variations have become available. For those who insist on having the switch shaft horizontal, there are right-angle gears to convert the vertical shaft of a board-mounted rotary to horizontal. Another option allows small rectangular pc boards to form switch stators that can be plugged into the main board (at a right angle), leaving the shaft horizontal.

**Standard rotaries hold their own.** Standard-design rotaries aren't out of it, though. They're still the workhorses (if there's enough space to accommodate them) for switching tasks that can't be handled by toggle switches. Standard rotaries are getting smaller, too. Half-inch diameter models that include all the standard design features are now commercially available. The smaller they become, though, the more difficult it is to maintain reliable performance. That's why a good half-inch rotary costs more than a larger one.

Whether the rotary switch is board-insertable or standard, at least two other trends are apparent. The first is toward standardization of both the design and materials used in construction. The other involves the use of precious-metal inlays at contact points only, rather than using solid precious metal or precious-metal coatings for the entire clip. How fast will inlay techniques become standard practice? That depends on precious-metal price fluctuations.

## Which switch? Some selection criteria

When you add switching to a bread-board setup to test circuit feasibility, rotary selection isn't too critical or difficult. Unused decks and contacts are normal at this stage. But when you're finalizing for mass production, you'll need to consider several factors that spell success or failure on the basis of performance or cost.

First, give attention to the electrical functions the switch must meet. You'll need the answers to many questions. How many poles? How many throws? What currents and voltages must be handled? Which clips will require make-before-break action and vice versa? Must the inactive clips at a given switch position be grounded?

**Lots of switching** in a little space—that's what can be accomplished when using a pc-board mountable model such as highlighted here.

Which clips will handle resistive loads, and which inductive? Will make-and-break currents differ from steady carry currents?

Next, think of the individual deck design. If common connections are a necessity between the front and back surfaces of a single deck or between adjacent decks, you'll need to specify clip positions that will accomplish this. Often, a rivet or eyelet instead of a jumper wire can provide these front-to-back connections.

Consider the general grade of switch required. Will low-cost stake construction suffice, or should a sturdier, repairable bolted construction be specified? Are precious-metal contacts needed? Will operating temperatures be a factor? What size switch can be accommodated on the chassis? How much detent torque will be required to give the switch a crisp "feel"? Will special insulation be required to meet high-impedance circuitry? Is its environment likely to be rough on the contacts or other parts of the switch?

These are the major questions to ask, but there are others. Let's move in for a close look at some of the switch-design options available for meeting various circuit requirements.

## High or low current?

High-current switching in home-entertainment or test equipment usually is considered anything over 1A of make-and-break current at 110V, or over 5A of carry current. Power switches for appliances offer a typical example. They can tolerate higher carry currents because a steady current flow does not cause arcing that would burn away the contacting surfaces.

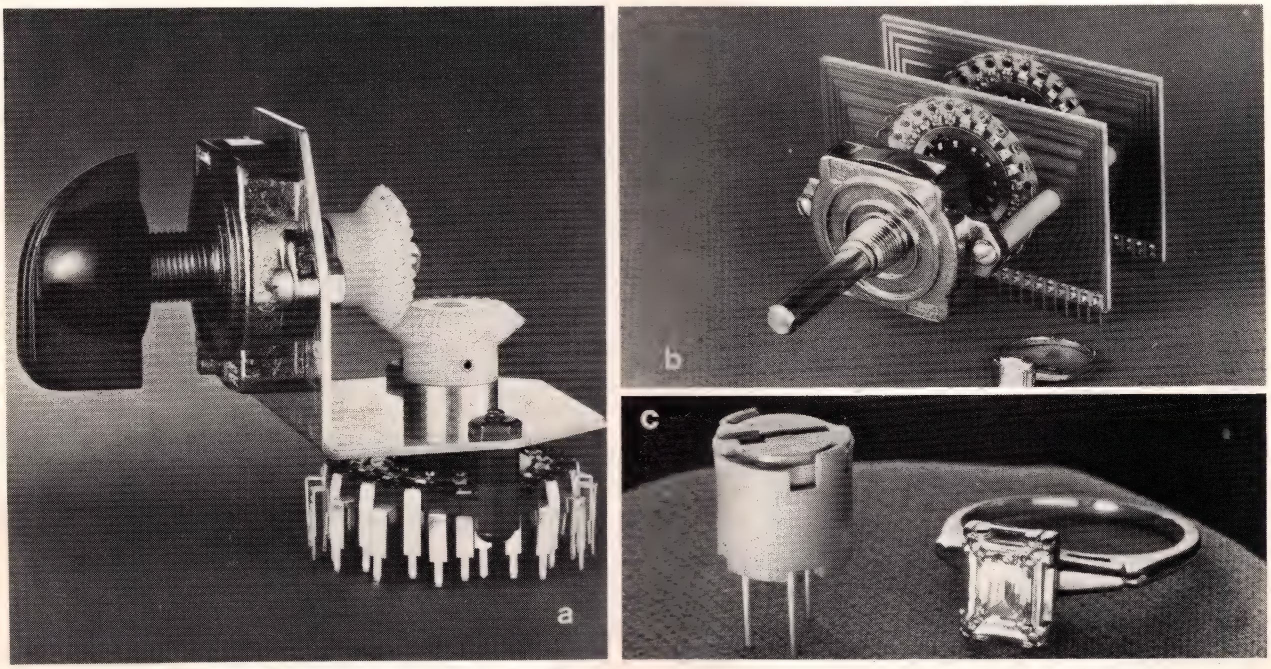
The selection of contact materials for high-current switches is less critical than for low-current ones. Enough power passes through the contact to punch through any ordinary oxide film or other insulating contaminant that forms on the surface during inactive periods.

Rotary switches that handle make-and-break currents of <1A at 110V (or carry current of <5A) are arbitrarily classified as low-current devices. When currents and voltages drop to quite low values, switch design and the selection of contact materials become more critical. Most of the factors involved in good switch design that we discuss in this article apply mainly to low-current switches.

Fortunately, when lower currents and voltages are involved, contact burnout as a result of dc or inductive-load arcing seldom is a serious problem. Contact materials and construction may be chosen without regard for either the voltage or the load type. Arc-suppression circuits are not required.

## Quality—dictated by the application

Two rotary switches that appear almost identical at first glance can vary widely in performance characteristics and longevity. Over-all switch quality depends on many factors, including mechanical design, contact metals, type of wafer



**Switches for mounting on pc boards** take many forms today: (**a**) A 32 position wafer switch with right-angle drive via gears (2-1/4-in. above-board height); (**b**) A low-profile 24 position commercial version; (**c**) Tiny 3/8-in. dia. rotary rated at 100 mA, 100V resistive.

insulation, type of detent and general corrosion resistance.

Rotary-switch manufacturers generally place their products in one of two categories—less-expensive designs for general use in home entertainment and test equipment, or rugged and expensive ones developed to meet strict government specifications.

A typical light-duty commercial unit rated for 10,000 cycles may have a leaf-spring detent, silver-plated brass contacts, phenolic insulation and staked construction. In contrast, heavy-duty commercial or industrial units, as well as switches designed to meet MIL-S-3786, will usually feature a dual-ball detent, silver-alloy contacts rated for 25,000 cycles, and insulation materials that possess higher mechanical strength. They will also withstand higher temperatures, have bolted rather than staked construction, and employ a corrosion-resistant finish that will pass a 50-hr salt-spray test.

In staked construction, the wafers are riveted by the projections that hold them permanently to the front mounting plate. The least expensive type of construction has the bushing staked directly to the front plate and stator, a leaf-spring detent and a single section with a maximum of three positions.

If more than three positions are required, low-cost staked-construction units with up to three sections are available. This construction is not sufficiently rugged to allow more than three sections, and will withstand less vibration, twisting, shock and stress than the bolted units. Another type of low-cost construction uses eyelets or rivets to hold the section on single-deck switches. These normally are fitted with a ball detent mechanism, and are comparable in strength and performance to single-deck strut or bolt construction types.

## Sizes, torques and detents

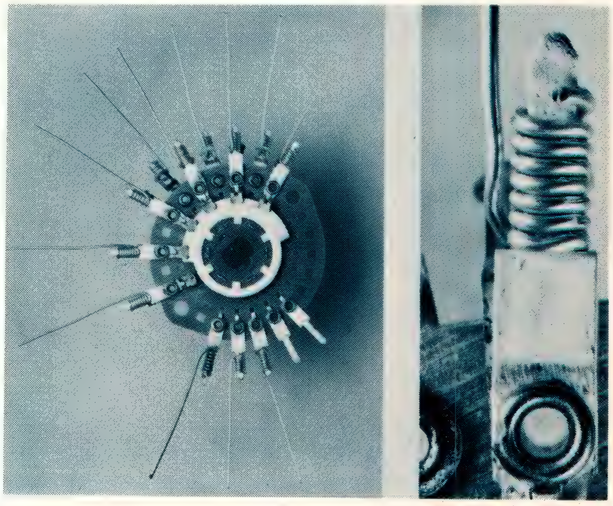
As you might expect, switch costs don't vary directly with sizes or diameters. Medium-size switches (1-1/4 to 1-9/16-in. dia.) are less expensive than either larger or smaller sizes. The two most popular sizes are 1-5/16 and 1-17/32-in. diameter, because with staked construction and four sections or less they represent the most economical utility units available.

One-inch diameter switches have the same reliability as larger versions, but run 50 to 75% higher in price than a comparable medium-sized unit. Half-inch diameter switches find use in military and ultra-miniature test equipment where space is at a premium. They cost about three times as much as a medium-size switch with the same number of contacts.

The 1-7/8-in. diameter models are mainly chosen for their heavier contacts and heavy-duty construction. Their larger contacts will handle more current (both make and break, and carry) than those on the smaller counterparts. Heavy-duty switch prices run about 50% higher than the popular medium-sized ones.

A subtle relationship exists between switch size, turning torque, knob size, and the detent force needed to give the switch action a crisp "feel." As you might expect, larger switches require large knobs, but even small switches constructed with high detent-force also may require large knobs.

Detent mechanisms generally match the cost and performance needs of the switches in which they are installed. The preferred type is the ball and starwheel. Here one or two balls are rolled from one notch in the starwheel to another against a spring of sufficient force to give the proper feel. This detent offers constant torque and crisp feel throughout a long mechanical life.



**Wire-wrapping rotary switch lugs** permit solderless connections on standard switches for those applications that use this wiring technique.

Knob size should match the total torque. For a comfortable turning force, the following knob sizes are recommended: 1/2-in. dia. knob for 8 to 15 oz. in. torque, 3/4-in. for 10 to 20 oz. in. torque, 1-in. for 15 to 35 oz. in. torque and 1-1/2-in. for 20 to 50 oz. in. torque.

## From schematic to switch section

A little extra time and care expended on the layout of clips, teeth and blades for each switch deck really pays off. It insures minimum switch-space requirements, fewer jumper wires, less cost and neater appearance.

When laying out blade design, be careful to specify whether you require nonshorting, positive shorting or special sequencing. Improperly specifying the shorting function can hasten contact burnout if dc arcs or inductive surges dissipate through the contacts.

Wherever possible, two or more circuits having the same common should be put on the front and rear of the same deck. Then common clips can be eyeletted, rather than wired together. Also, when components are wired between decks, you should try to keep corresponding contacts in the same relative position on the decks for neater, easier wiring. Before designing special-application sections and switches, it's always best to consult the switch manufacturer. Frequently he can suggest additional ways to improve the product or reduce its cost.

## Insulation: properties and prices

The most economical and widely used rotary switch insulation material is paper-base phenolic. It's common in commercial switches for home entertainment appliances, but should not be used at operating temperatures over 85°C.

Ceramic costs more than phenolic, but is mechanically stronger, more rigid, and has higher insulation resistance. Ceramic decks can operate up to 150°C, limited by the contact materials. They usually are coated with silicone fluid to prevent surface wetting. After this treatment, moisture tends to form isolated surface droplets, thus avoiding the drop in insulation resistance that otherwise would occur.

As an insulator, ceramic has a higher dielectric constant than phenolic or most other materials in use. Fortunately there is very little change of its dielectric constant with temperature or frequency.

Still more expensive than phenolic or ceramic is a hybrid construction that involves two materials—glass silicone or glass epoxy for the stator and Kel-F for the rotor. The Kel-F provides excellent insulation, and gives smooth rotor operation within the glass-silicone stator. Maximum operating temperature (limited by the Kel-F rotor) is 85°C. This combination is used widely in high-impedance circuits or applications demanding high insulation resistance and low dielectric constant. It has little water absorption, is tough, and will withstand heavy shocks. For a more economical deck with similar strength but reduced insulation resistance, a phenolic rotor can be used with a glass-epoxy stator.

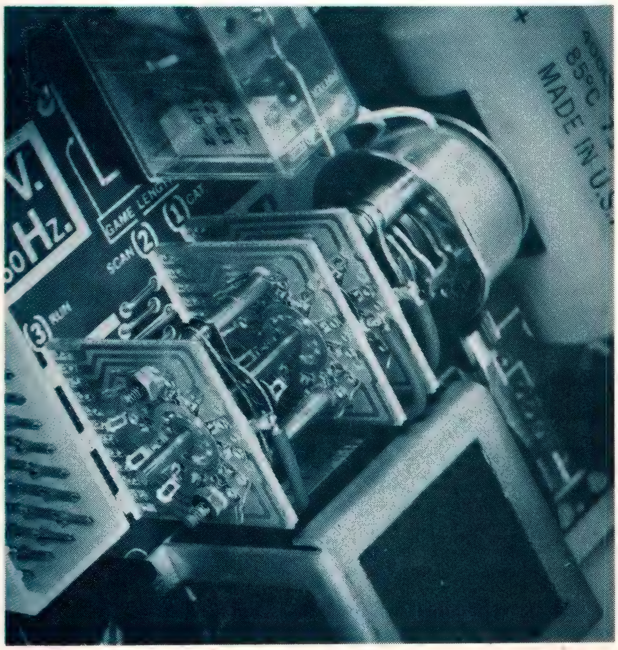
Decks molded from diallyl phthalate have electrical characteristics similar to those of glass silicone. Because it is possible to achieve very close dimensional tolerances with molded construction, contact placement can be more exact, and insulation ridges can be used between contacts to increase the insulating surface path.

## Anatomy of an electrical contact

Double-wiping sliding contacts are preferred in modern rotary switch designs. Here the sliding metallic blade enters the jaws of the clip to effect contact on both sides of the blade. The flared sides of the jaws act as a guide to help center the contact blade, thus minimizing contact opening due to shock or vibration. If these forces cause one jaw of the contact to lift from the blade, the opposite jaw is forced into better contact. It's at these two points of contact between the blade and clip that the electrical action takes place. How well the switch functions, then, depends greatly on the metals in contact at these points.

Four general approaches permit making a solid electrical contact between two metals. The simplest, but perhaps most expensive way, is to make the contacts from gold. Gold is a good conductor, and unique among metals in that it doesn't form an insulating oxide film on its surface under most conditions. Light pressure on gold-gold contacts completes the electrical junction.

A second method, mentioned earlier, involves forcing enough current through the junction to break down oxide layers or other contaminant films. For most metals other than gold, even freshly machined surfaces start to oxidize in air in a matter of seconds. For "dry" circuits (those where very small voltages and currents are present), insufficient voltage may exist to penetrate the oxide film. In that case, two other ways allow you to achieve electrical contact: either apply enough mechanical pressure to break up the oxide film, or apply both pressure and a



**Remote control of switches** can be accomplished readily by driving them with a rotary solenoid. Bolted construction gives flexibility of location for all components including the solenoid.

wiping action to sweep away the oxide film debris and produce freshly "machined" metal surfaces. All four of the above techniques find use in rotary switches.

## Proper metal—proper contact

For "wet" (high voltage and current) circuits, ordinary brass can be specified. Brass plugs and sockets, for example, are used almost universally for connecting household appliances to wall sockets. With dry circuits, however, the proper metal will be dictated by several factors:

- The "dryness" of the circuit;
- The ambient operating temperature;
- The "life" desired (number of operating cycles);
- The desired contact resistance (both initial and after long use);
- The blade-clip drag;
- The cost of the metal itself, or of rolling or plating the selected metal on a cheaper underlying metal.

Some general comments seem called for here. Whatever the metal selected, the simplest construction uses it for the entire contact. But even at precious-metal prices of 20 years ago, this approach was considered costly. Consequently, rolling or plating precious metals on spring brass or other common alloys has become widespread over the years. Plating gives a relatively soft, porous overlay. Therefore, when additional abrasion resistance and longer contact life are a necessity, manufacturers use rolled-on inlays or overlays.

At today's precious-metal prices, contact construction tends toward thinner plated or overlaid coatings, and the latest trend sees precious metals used only at the exact point of contact.

Gold, when used over silver, generally prevents tarnish of the silver surface, improving shelf life and enhancing solderability.

Typical contact surfaces currently available from rotary switch manufacturers are silver-plated brass, silver alloy (plain or gold plated), gold-plated brass and gold-plated special nickel alloys. Where there must be improved abrasion resistance (hence, longer life), gold or gold alloys are rolled on rather than plated. These materials, when used in a double-wiping contact clip, give contact resistances in the range of 0.003 to 0.015Ω on initial contact. Surface finish of rolled precious-metal alloys generally falls within the range of five to 10 microinches.

For low-power applications, silver-plated brass with 0.0001-in. minimum plating will provide a silver-to-silver contact for more than 10,000 cycles.

Nickel-alloy spring base material with hard gold alloy rolled on the surface gives gold-to-gold contact for 50,000 to 100,000 cycles (to 150°C). Silver alloy with 0.0005-in. hard gold alloy rolled on the surface likewise will yield gold-to-gold contact for 50,000 to 100,000 cycles to 100°C. This contact material performs very well in dry-circuit applications.

Normally, manufacturers use silver-plated brass contacts to interrupt no more than 1A (resistive load) at 28V dc or 0.5A at 110V ac for 6000 operations. Silver alloy may be used to break current on a resistive load of 1A at 110V ac for 50,000 operations.

## Don't let the frames rust off!

After you've decided on the proper contact metals for your switch applications, be sure to give some thought to the metals used in the supporting structure. Switch life shouldn't be limited by having it fall apart due to frame corrosion. Usually some plating or chemical treatment is required.

For commercial or military use, parts will be cadmium or zinc plated with a full-protection golden chromate dip. A switch so treated will withstand the 50-hr salt-spray test demanded by MIL-S-3786, and will hold up well in tropical environments.

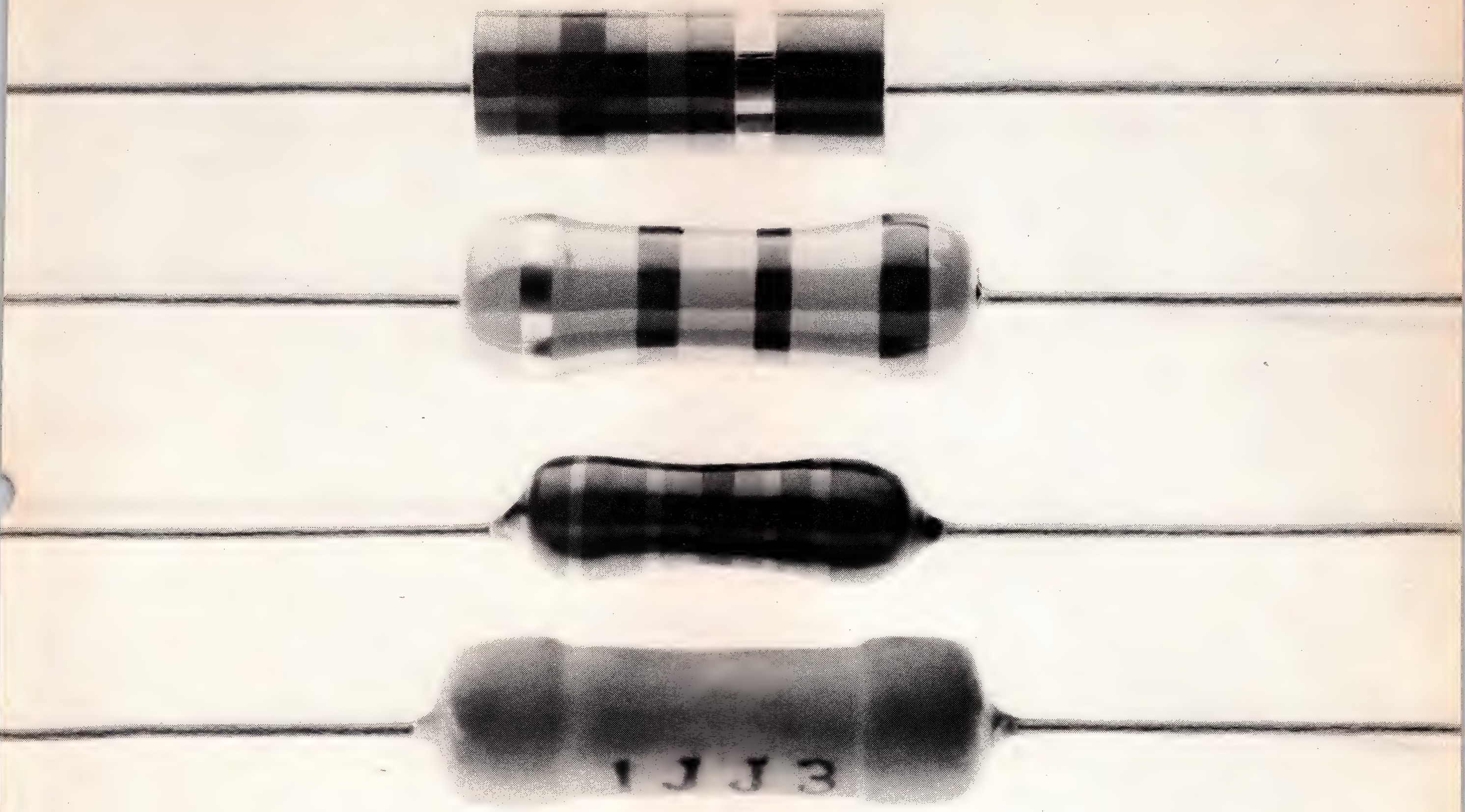
## New or old, rotaries still click

Despite inroads by electronic switching and the fact that rotaries are far from their infancy, their use continues at a high level.

The newer forms that either are on pc boards, or that plug directly into these boards, have had much to do with this. So has the widespread adoption of techniques that conserve precious metals. Precise placement of precious metals only at the contact points, for example, does this very effectively. ☐

## Author's biography

**Bernard J. Golbeck** is Director of Engineering at the Oak Industries, Inc. switch division in Crystal Lake, IL. Fourteen years with Oak, he previously was Chief Engineer at Erwood, Inc. Bernard holds a graduate P.D. (Professional Development) degree from the Univ. of Wisconsin, is a member of ASME, and has been granted 19 patents.



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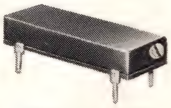

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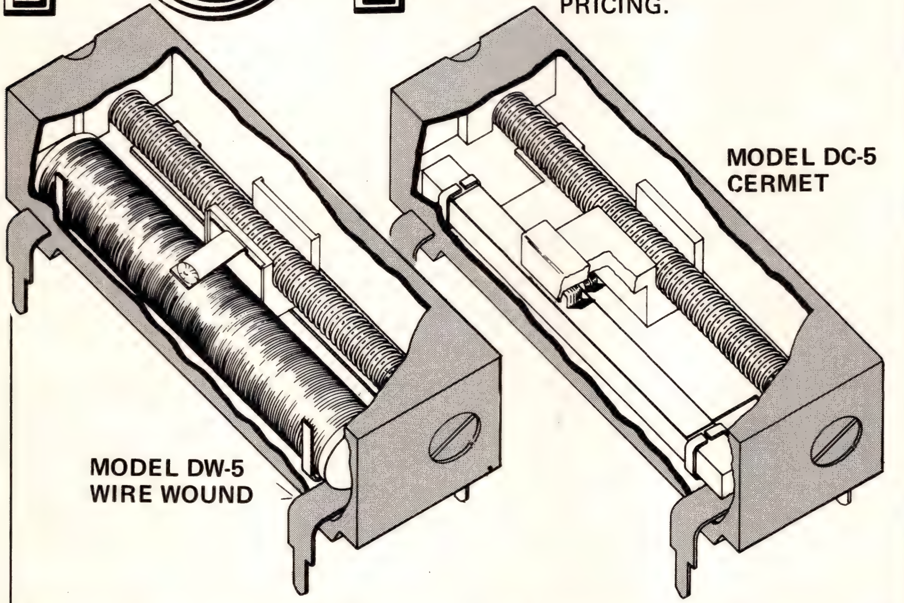

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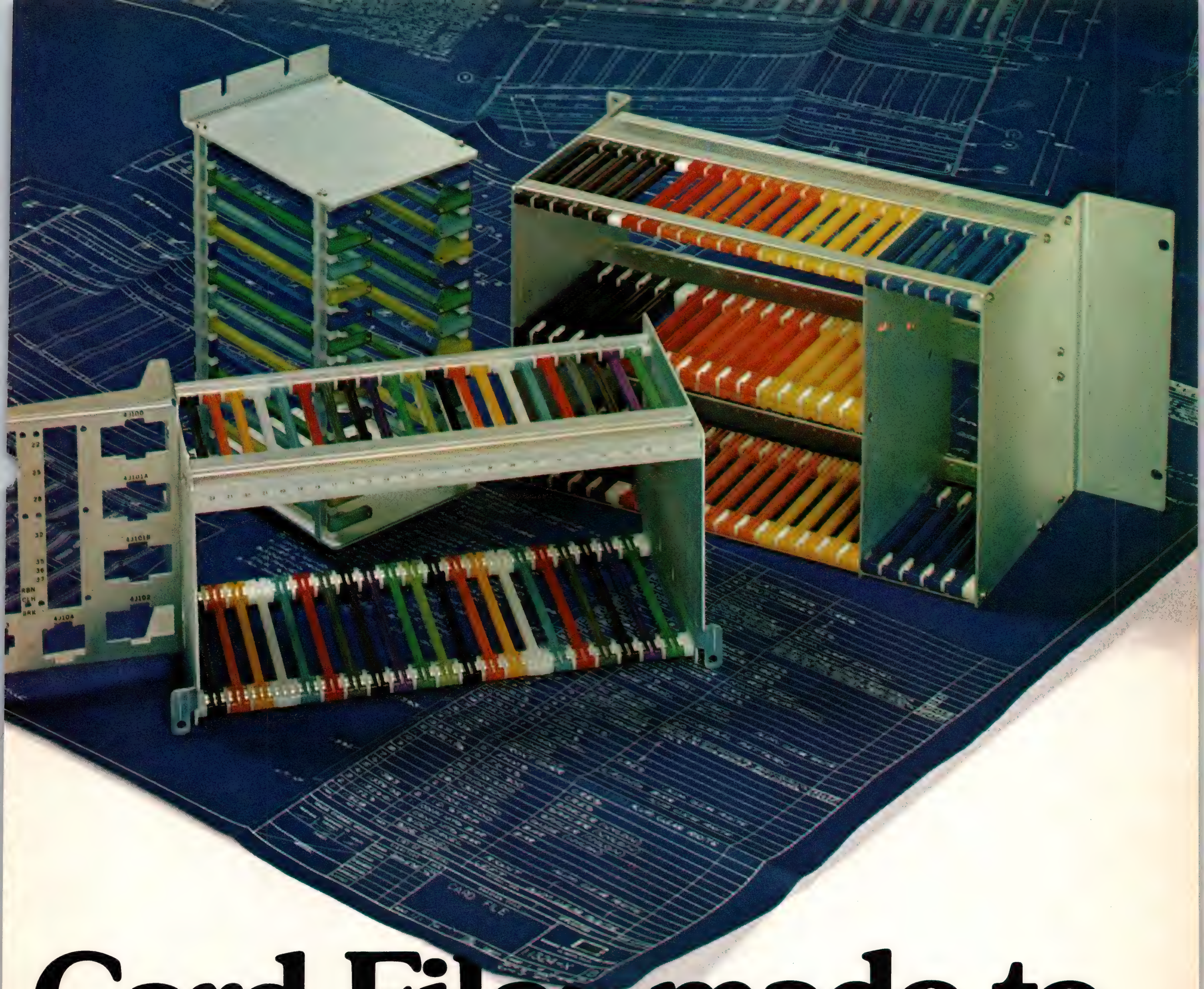

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# Time is money

An old proverb states "Time is Money." Today's technical jargon might express this as: The logic which does the greatest work per unit time, per dollar, *can reduce equipment costs*. Naturally, we feel the logic is MECL. Here are a few actual case histories illustrating just that.

**Case 1.** A processor was designed in three ways: A. Schottky TTL, performance level X; B. MECL 10,000, same structure, performance 2X; C. MECL 10,000 architecture modified to exploit ECL speed and other design advantages, performance level X. The design team discovered the following:

| | TTL (Schottky) | MECL 10,000 |
|---|---|---|
| Performance | X | X |
| Package Count | Y | Y-25% |
| Power Consumption | P | P-28% |
| TOTAL SYSTEM COST | Z | Z-22% |

**Case 2.** Existing equipment used 3 TTL (7400 series) boards (~100 packages each) to process 9 input lines of 2 to 10 MHz data streams. The system was redesigned and the 3 boards replaced with *one* MECL 10,000 board (~100 packages) which worked more than 3 times faster.

Design results: A. A small saving in basic IC component costs; B. A huge reduction in system complexity, together with increased reliability, smaller size, reduced power consumption, lighter weight, and reduced assembly costs.

**Case 3.** A memory system was designed which would have required high performance NMOS memories and would have used TTL control logic. In analyzing the system, designers realized that delay time subtracted from control logic operation could be added to NMOS cycle time specs. Thus, the use of cheaper, lower performance NMOS memory elements were combined with ECL control circuits. Design goals were met and the same level of performance was obtained — at reduced cost.

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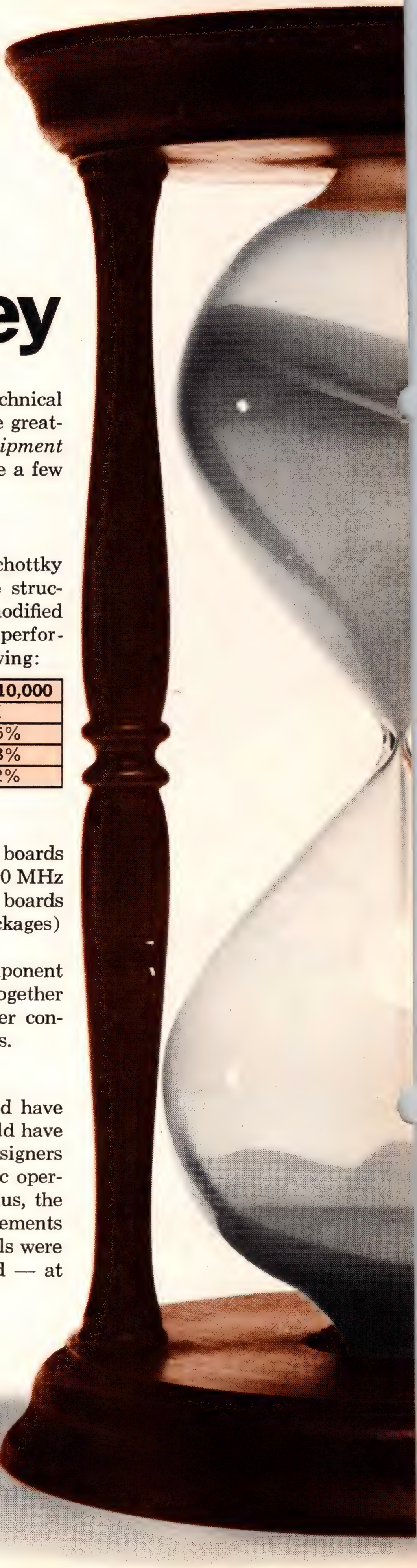
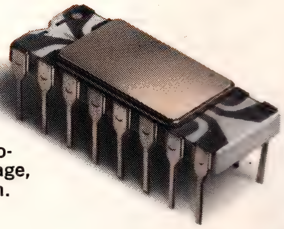


# MECL saves time



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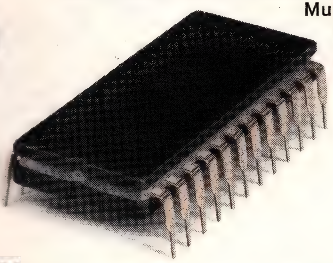

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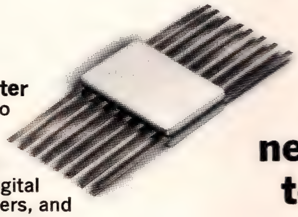

**MC1699 ÷ 4, 1-GHz Counter**
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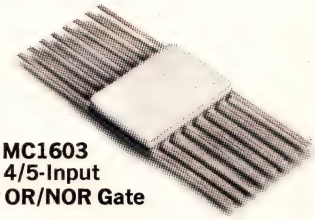

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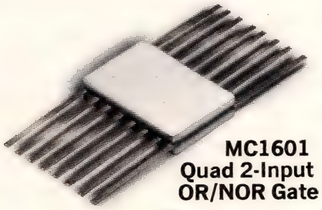
**OR/NOR Gate**



**MC1601**
**Quad 2-Input**
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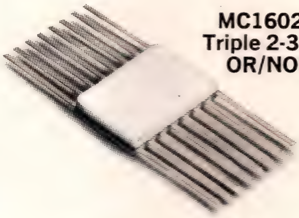

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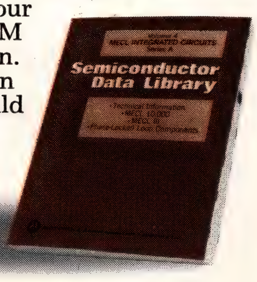

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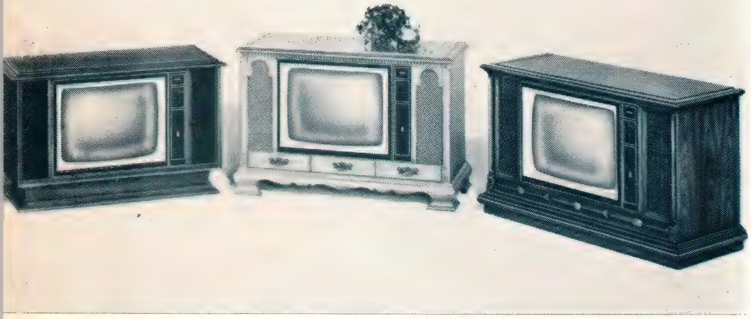
# EDN 4th Annual Creative Design Contest

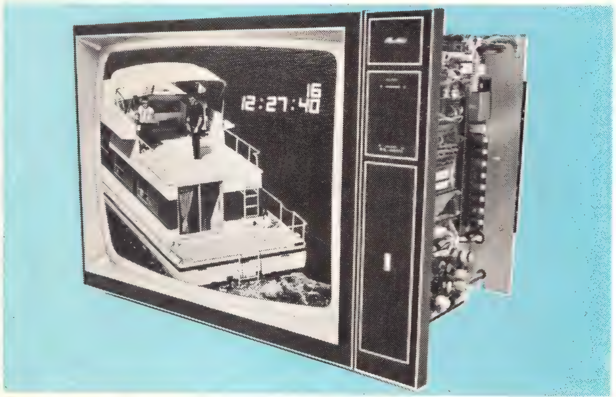


**First prize, a 25-in. color-TV kit** is available in a choice of cabinet styles; Contemporary, Early American or Mediterranean.

This year's contest promises more fun and games than ever before. Five of the prizes, including First Prize, will provide you with many hours of delight as you assemble them, and years of satisfaction as you use them.

**First prize is a Heathkit Model GR-2000 Digital Color TV** with 25-in. screen, remote control, on-screen digital clock, built-in dot generator for convergence, 16-channel programmable tuning, and a choice of either Mediterranean, Contemporary or Early American pre-finished cabinet. (See EDN, Sept. 5, 1974, pg. 14 for more details on this TV.) Total value is $945.

Nine additional prizes will also be offered, plus a bonus prize. Four of these will be a combination prize—a Heathkit GR-1075 **AM/FM Digital Clock Radio** featuring a planar gas-discharge display, internal standby battery supply and 24-hr. alarm cycle; and a Heathkit GC-1093 **Digital Car Clock/Timer** also featuring a planar gas-discharge display as well as elapsed-time capability. Total value of this combination is $200.



**Color, TV kit features** on-screen channel number and time display, pushbutton digital tuning and volume control, remote control operation and built-in dot generator for convergence.

The remaining five prizes are Novus (National Semiconductor) **Digital Wristwatches**. These feature a LED readout with hours, minutes and seconds displayed at a touch of a button. The watches have a gold case and band, and are worth $220 each.

A **Bonus Prize** will be awarded this year to the winning entry that uses the most products advertised in the January 5 and 20 issues of EDN. This prize, a Heathkit **Digital Indoor/Outdoor Electronic Thermometer**, uses a planar gas-

**Combination second prize** includes an AM/FM digital clock-radio and a digital car clock/timer. Both feature planar, gas-discharge readouts.

**Five Novus digital wristwatches** round out the second prizes. These watches feature LED readouts, gold-plated case and gold-plated stainless-steel bracelet with fold-over buckle.

discharge display. The kit includes an 85-ft. cable for customizing any two temperatures you wish to measure.

## Here's how to enter

Any reader may enter this contest (subject to contest rules restrictions). Just study the January 5 and 20 issues of EDN very carefully; put your "creative cap" on; and then set your imagination wandering. The resulting design can be well worth your time and effort, particularly if you win. Use the most products advertised in the two January issues and if you turn up as one of the top 10 winners, you also win a bonus prize.

Make sure your entry package is complete or your design will be disqualified. The package should include: schematics, drawings, diagrams, description of operation, photos (if available) and a list of the advertised products used (including page number and issue date).

### 1st Prize:

Heathkit 25-in. color TV kit with remote control, digital clock, 16-channel-programmable electronic tuning and choice of cabinet style. Value $945.

### Nine 2nd Prizes:

Five Novus (National Semiconductor) digital wristwatches; gold case and band. Value $220. Four combinations—Heathkit AM/FM digital clock radio and Heathkit digital car clock/timer. Value $200.

### Bonus Prize:

Heathkit digital indoor/outdoor digital thermometer. Value $63.

## Contest Rules

1. Entries must be postmarked no later than midnight April 5, 1975.
2. All designs must be related to devices to be used in and around the home, auto or recreation vehicle.
3. Circuit entries must not contain confidential information or create patent problems.
4. Designs must be original with author(s) and must not have been published previously (limited-distribution house publications excepted), and must have been constructed and tested.
5. Exclusive publishing rights remain with Cahners Publishing Co.
6. Last year's winners are not eligible to enter.
7. Employees of Cahners Publishing Co. or members of their families may not participate in the contest.

## How entries will be judged

All entries will be judged by the Editors of EDN on the following basis:

1. Technical competence and utility—is the design real and will it work?
2. Creative imagination. How unique and original is your idea? Does it perform a needed and useful function? Is it a source of fun? Will other designers be turned on by it?
3. For the bonus prize only—the number of different advertised products used.

Fill it in, attach it to your entry package and mail to:

**4th Annual EDN Creative Design Contest,**
**221 Columbus Avenue, Boston, Mass. 02116**

**Name** ______________________ **Company** ______________________
**Address** ______________________ **Address** ______________________
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**Name and Function of your entry** ______________________________

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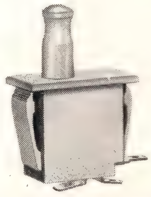

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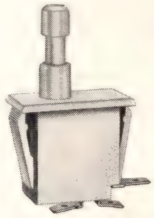

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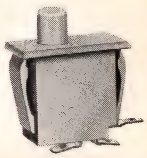

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†$V_{CEO}$ measured at 10 mA    *Forced gain = 100

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# Contest winners create designs capable of becoming standard IC's

*Monochip creations show a degree of creativity that could advance the state-of-the-art. The 'best and the brightest' are described.*

**Hans R. Camenzind,** Interdesign

With the monochip, the creation of a custom IC has become a straightforward task, no more difficult than designing an ordinary transistor circuit or a pc board. Interdesign's monochip method enables the designer to shrink the entire prototype cycle to less than three weeks—compared to at least six months for an ordinary custom IC.

Though the EDN/Interdesign Contest was created for neophyte designers, the winners showed a sophistication beyond normal competency. None of the contestants were IC design experts, nor had any of them ever designed an IC before.

A very distinguished panel of design experts was assembled for the difficult task of judging. Jerry Graeme of Burr-Brown, Paul Brokaw of Analog Devices, Durward Priebe of Hewlett Packard and Jim Ball of Interdesign rated the designs on:

- Ingenuity—how ingenious a product is it?
- Interest—will it interest the readers of EDN?
- Technology—how does the design fit IC technology?
- Application—how is the monochip used?

## Introducing the Grand Prize Winner

Doug Curtis entered the contest to achieve one of his life-long goals. He hopes to build a music synthesizer and his winning design was a radical, yet inexpensive, building block for it.

A music and speech major in college, Doug presently is unemployed by his own choice. Spending most of his youth in Europe, he recently toured America.

| Rank | Winner | Design | Prize |
|---|---|---|---|
| 1 | Douglas Curtis | Linear/Log Mult. | H.P. 65 Calculator |
| 2 | Allan Hamilton | Op Amp | Tekelec Digital Voltmeter |
| 3 | Gerald Stanley | VU Meter | · · |
| 4 | Benjamin Glass | Combination Lock | · · |
| 5 | Robert Brown & Steve Hall | Switching Regulator | · · |
| 6 | Robert Howell | Control Circuit | DTS 1300 Voicecaster |
| 7 | Donald Lancaster | Keyboard Encoder | · · |
| 8 | Thomas Marker | PLL/Frequency Generator | · · |
| 9 | Charles Croskey | VCO | · · |
| 10 | Fred Kiko | Voltage Reference | · · |
| 11 | Brent Andreasen | A/D Converter | · · |
| 12 | Winston Clark | Quad Level Translator | · · |
| 13 | Frederick Hauer | Transmitter Control Circuit | Volt-Clock |
| 14 | Alan Faris | Programmable Gate | · · |
| 15 | Franklin Ramsey | Sweep Generator | · · |
| 16 | C. Balmer | PDM Demodulator | · · |
| 17 | Harvey Morgan | Bandwidth Compressor | · · |
| 18 | Robert Calkins | Sample and Hold Amp. | · · |
| 19 | William Maserang | Pulse-Position Modulator | · · |
| 20 | Bruce Cohen | Video Amplifier | · · |
| 21 | J.M. Rochelle | Transmitter | · · |
| 22 | Ewan MacPherson | Logarithmic Transimpedor | · · |
| 23 | Joseph Tobin | Clear Channel Detector | · · |
| 24 | Arthur Berg | Pulse Width Converter | · · |
| 25 | Don Leonard | Quad One-Shot | · · |

# Linear/log multiplier displays novel approach

**Douglas R. Curtis**

Multipliers produce the linear relationship:

$$V_0 = KV_xV_y \qquad (1)$$

Electronic music synthesizers and sweep function generators prefer $V_0$ to vary exponentially with the control voltage. My goal, therefore, was to design an IC multiplier with the relationship:

$$V_0 = Ka^{V_x}\,V_y \qquad (2)$$

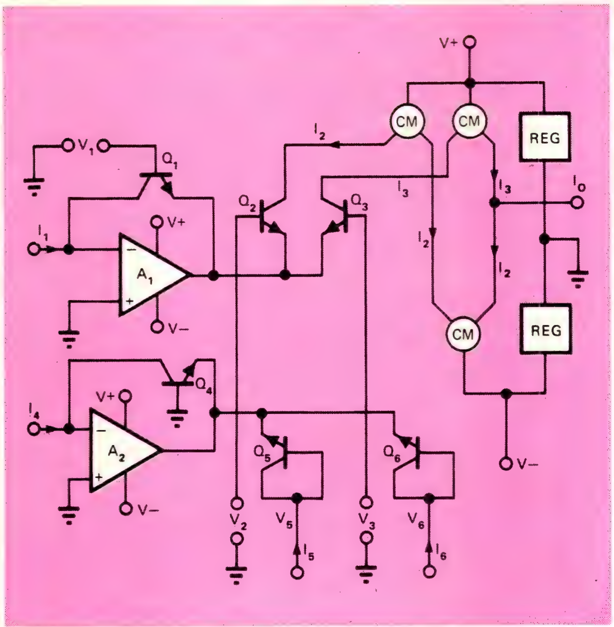


**Fig. 1—Grounding the base** of $Q_2$ or $Q_3$ and connecting $V_6$ to the base of $Q_3$ or $Q_2$ is an alternate way of obtaining transconductance multiplication or division from the basic linear/log multiplier circuit.

in addition to the standard linear output.

To give the op amp the flexibility to drive a VCO or the summing junction of an integrator, it should have a current output. This, then, was an alternate goal. Moreover, because the transconductance of multipliers is temperature sensitive, my design eliminates this parameter as a problem. As a final step, I made the unit capable of decoding and designed it to fit into a standard 14-pin DIP.

## Let's talk about basics

In the basic circuit (**Fig. 1**), $A_1$, $Q_1$, $Q_2$ and $Q_3$ form a conventional antilog converter where:

$$I_2 = I_1 e^{(V_2 - V_1)/h} \qquad (3)$$

$$I_3 = I_1 e^{(V_3 - V_1)/h}$$

$$h = \frac{KT}{q} \qquad (4)$$

Three current mirrors invert currents $I_2$ and $I_3$ so that the high-impedance current source output provides $I_O = I_3 - I_2$. When $V_2 = V_3$, $I_2$ equals $I_3$, and $I_O = 0$.

A differential voltage applied to the bases of $Q_2$ and $Q_3$ causes an output current to flow. This current's polarity depends upon the polarity of the differential voltage, while its magnitude depends upon $I_1$ and $V_1$. If the base of $Q_2$ is grounded, and a small signal, $V_s$, is applied to the base of $Q_3$, the output current will be:

$$I_O = I_1 e^{(V_1)/h} \left(e^{(V_s)/h} - 1\right)$$

If $V_s$ remains small, ($|V_s| < h$), the quantity ($e^{V_2/h} - 1$) will be nearly linear with $V_s$. Hence, the output current forms a product of the input signal, $V_s$, $I_1$ and $e^{-V_1/h}$, and a 2-quadrant multiplier results with either a linear or exponential control scale.

This approach has several shortcomings, however. To get < 1% distortion, $V_s$ must be kept quite small. Thus, The S/N ratio becomes inadequate. Moreover, a small signal ac circuit analysis shows that due to the unsymmetrical nature of the $e^x$ function, the output ac signal contains a dc component whose size increases with the amplitude of the ac input. This characteristic makes the circuit worthless when used with integrators in voltage-controlled filters. Finally, the small signal transconductance of the multiplier is temperature sensitive:

$$g_m = \frac{dI_O}{dV_s} = \frac{I_1 e^{-V_1/h} e^{V_s/h}}{h}$$

For small $V_s$ close to 0,

$$g_m \approx \frac{I_1 e^{-V_1/h}}{h}, \quad h = \frac{KT}{q}$$

You can overcome all of these problems by first taking the logarithm of the input signal before it is applied to the base of $Q_2$ or $Q_3$. Diode-connected transistors $Q_5$ and $Q_6$, plus $Q_4$ and $A_2$ make up the log converter. If you apply $V_5$ and $V_6$ to the bases of $Q_2$ and $Q_3$, respectively, the following relationship holds:

$$V_1 - h \ln \frac{I_1}{I_{s1}} = h \ln \frac{I_5}{I_{s5}} - h \ln \frac{I_4}{I_{s4}} - h \ln \frac{I_2}{I_{s2}}$$

$$V_1 - h \ln \frac{I_1}{I_{s1}} = h \ln \frac{I_6}{I_{s6}} - h \ln \frac{I_4}{I_{s4}} - h \ln \frac{I_3}{I_{s3}}$$

Assuming $I_{s1} = I_{s2} = I_{s3}$ and $I_{s4} = I_{s5} = I_{s6}$ for well-matched transistor pairs:

$$V_1 = h \ln \frac{I_5 I_1}{I_4 I_2} = h \ln \frac{I_6 I_1}{I_4 I_3}$$

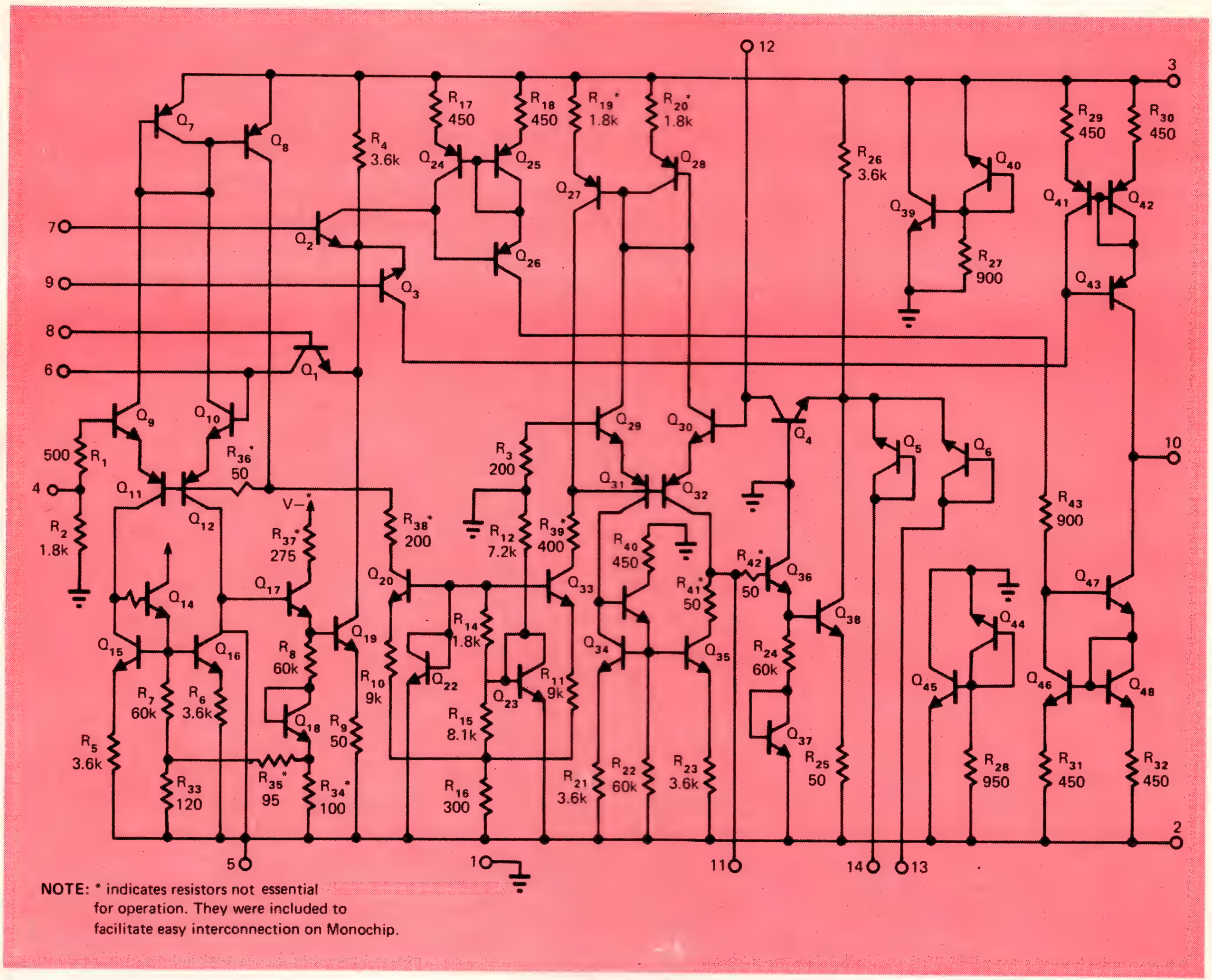
$$I_2 = e^{-V_1/h} \frac{I_5 I_1}{I_4}, \quad I_3 = e^{-V_1/h} \frac{I_6 I_1}{I_4}$$

$$I_O = I_3 - I_2 = e^{-V_1/h} \left[\frac{I_1}{I_4}(I_6 - I_5)\right]$$

This final equation shows that the output current is a linear product of the differential input current, $I_6 - I_5$, the ratio $I_1/I_4$ and the exponential term $e^{-V_1/h}$ This results in a 2-quadrant transconductance multiplier with either exponential or linear control and with a division capability. Distortion depends only on the accuracy of the log elements and is typically under 1% over a wide range of input and control currents. Also, the transconductance is insensitive to temperature:

$$g_m = e^{-V_1/h} \left(\frac{I_1}{KI_4}\right)$$

The only temperature compensation needed is for the exponential control voltage, $V_1$



NOTE: * indicates resistors not essential for operation. They were included to facilitate easy interconnection on Monochip.

**Fig. 2—Tightly controlled current source** ($Q_{20}$–$Q_{23}$) supplies each op amp with precisely 4 μA of current. Monochip design achieves multiple goals of providing both linear and log transfer functions, providing a current output and eliminating problem of temperature sensitivity and transconductance.

The output of the log converter drives the input of the antilog converter. Hence, it could be connected internally. However, the log converter outputs and the antilog converter inputs are brought out on separate pins to facilitate the IC's use in voltage-controlled oscillators. In the oscillator configuration, I do not use the log converter portion at all. The bases of $Q_2$ and $Q_3$ are switched alternatively from 0 to a negative voltage just great enough to turn the particular transistor completely off. Output current then alternatively charges and discharges a capacitor. The magnitude of the current, and therefore the frequency, is either linearly controlled by $I_1$, or exponentially by $V_1$ through the following relationship:

$$I_0 = \pm e^{-V_1/h} I_1$$

## And now for the real thing

In addition to the log elements, the circuit consists of two operational amplifiers and a common current source to bias them, plus three current mirrors and two voltage regulators.

Because the op amps have a specific purpose, their performance requirements are also specific and, in most cases, less stringent than those for even general-purpose op amps. The most important amplifier errors in this application are input bias and offset currents, offset voltage, and their temperature coefficients. Hence, the input stage is most crucial and a large open-loop gain, most desirable.

Open-loop output impedance is not important, as long as the output can deliver the largest currents required. Nor are high-slew rate and large-output voltage swings necessary, because the output voltage generally swings only 200 to 300 mV. A large common-mode or differential-input voltage range is also unimportant since the two inputs always remain at ground. Finally, short-circuit output protection isn't required.

The input differential stage **(Fig. 2)** is identical to 741, 776, 777 or 301 designs, but is biased at a much lower current to keep the input currents low. You only sacrifice frequency response and slew rate, but these again aren't critical. Since the log transistors operate at currents between 0.5 $\mu$A and 0.5 mA, the input currents must be at least an order of magnitude lower. I chose a stage bias current of around 4 $\mu$A to obtain input currents of less than 30 nA. For greatest accuracy, the input currents can be externally nulled out.

The second or output stage, a Darlington pair, simply provides gain. The collector of $Q_{17}$, connected to a low-impedance point, eliminates the Miller capacitance loading on the first stage. I chose the load resistor for a quiescent current drain of 2 mA to keep the operating current point relatively unaffected by the log transistors.

The most unconventional op-amp circuitry is the current source that biases the two op amps. Since the input currents to the op amp should be as stable and controlled as possible, the performance of this current source has to be controlled tightly. It must supply each op amp with precisely 4 $\mu$A of current. In addition, it must give these currents a temperature coefficient that will cancel the temperature variance in the input currents due to changing $h_{fe}$. A coefficient of + 0.5%/°C will not only reduce the temperature change in input currents, but will compensate for the − 0.33%/°C shift in transconductance of the input stage. I accomplish this precise temperature coefficient by feeding a small voltage with a negative temperature coefficient into the emitter circuit of the current source.

Since the tolerance of pinch resistors is too large, you have to derive the small currents using only small valued resistors. About 1 mA of current flows into diode $Q_{23}$ causing about 45 $\mu$A to flow into diode $Q_{22}$ as determined by $R_{14}$. $Q_{20}$ and $Q_{21}$ then divide this current to give the desired 4 $\mu$A of sink current. A portion of the voltage across diode $Q_{23}$, which has a negative temperature coefficient, is applied to the emitters of $Q_{20}$ and $Q_{21}$ to give the desired coefficient of + 0.5%/°C.

## A family grows

One of the many possible applications for this monochip is shown in **Fig. 3.** This circuit is by no means complete, since I omitted provisions for nulling out the quiescent output current of the circuit or op-amp input currents.

In all applications, input signals and control voltages are converted to the required currents through resistors. When this method provides the signal currents to $Q_5$ or $Q_6$, however, the conversion becomes somewhat nonlinear. This is due to the nonlinear relationship between the junction current and voltage of the diodes. Lowest error results when the input voltages are large compared to the junction drops. With the ±10V used in the sample

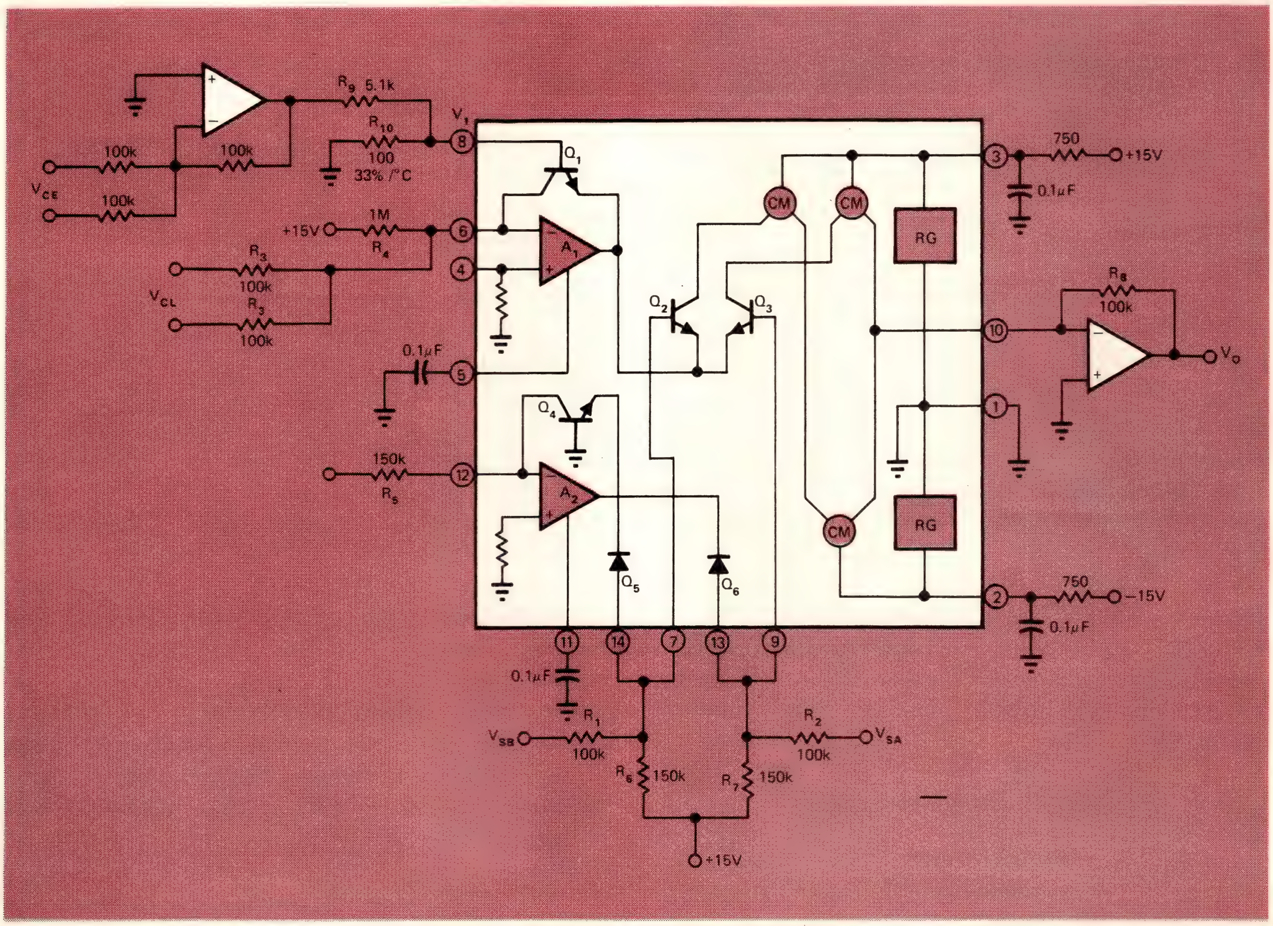


**Fig. 3—This VCO,** with differential inputs and linear/exponential controls, can achieve high Q's with unconditional stability. It can also be used in an audio frequency spectrum analyzer.

applications, the error is so small that it is omitted from the design equations. However, if you use smaller input voltages or require greater accuracy, an appropriate voltage-to-current converter is needed to supply the signal currents to these inputs.

In the linear multiplier/divider configuration, all log transistors are biased quiescently at around 0.1 mA. When you use the exponential control input, log transistor $Q_1$ is biased at 15 $\mu$A, or at the mid-point in the planned operating current range. This keeps the $|V_1|$ excursions at a minimum and hence minimizes temperature effects of the $e^{-V_1/h}$ term. Use of a temperature compensating resistor in the base circuit further reduces this effect.

Another application for the linear/log multiplier IC is in electronic music synthesizers, where most functions provide exponentially scaled output quantities. In music, pitch is heard in octaves, and volume in decibels. The voltage-controlled oscillators, voltage-controlled amplifiers, voltage-controlled filters and transient generators must all be scaled exponentially.

In such an application, one of the most valuable features of the Monochip is that all of the major and most repeated units of a synthesizer—VCO's, VCA's, VCF's, transient generators and balanced modulators—can be built around the same IC. This universal quality makes its use not only economically feasible but quite desirable. □

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# Current op amp has limitless potential

**T. Allan Hamilton**

Op amps have become familiar items. Their availability and simplicity of use have caused an entire family of products to be designed quickly and efficiently.

However, op amps are primarily voltage devices with limited operation. For instance, voltage-controlled current sources or current-controlled current sources cannot be synthesized with single units.

## Increase versatility the easy way

Current op amps (COA's) have major advantages over voltage op amps (VOA's). COA's require current gain, not voltage gain, and this is implemented far more easily with bipolar transistors. If voltage swings stay low, COA's have very large bandwidth because Miller feedback capacitance limitations, inherent in VOA's, are of no consequence.

The ease of generating tracking and matched current sources in monolithic form is well documented. If you use these techniques, additional tracking outputs can easily be generated, enabling increased application versatility with almost no increase in cost.

A COA's input stage requires a low-differential input impedance, differential-current inputs and differential-current outputs to further gain stages. In this realization **(Fig. 4)**, a pair of composite pnp transistors, $Q_{13}$ and $Q_{14}$ and $Q_{15}$ and $Q_{16}$, are used in a differential common base mode. The inputs occur at the emitters of the pnp transistors; the outputs, at the collectors. Biasing for the bases of these transistors is accomplished with diode-connected transistors $Q_{19}$ and $Q_{20}$.

| VOA (Standard Op Amp) | COA (Current Op Amp) |
|---|---|
| Infinite Voltage Gain | Infinite Current Gain |
| 2 Voltage Inputs (differential) | 2 Current Inputs Current (differential) |
| Single (or dual) Voltage Output | 2 Current (differential) Outputs |
| Additional Outputs Difficult to Generate | Additional Outputs of either polarity, simple to generate |
| Bandwidth limited by Miller Feedback caps & voltage gain | Bandwidth limited by fundamental limitations of transistors & output voltage swing in realizations |
| Useful for Current Controlled Voltage Source and Voltage Controlled Voltage Source | Can generate Current Controlled Voltage Source (CCVS)<br>Voltage Controlled Voltage Source (VCVS)<br>Current Controlled Current Source (CCCS)<br>Voltage Controlled Current Source (VCCS) |
| Input and Output in general require ground reference | Inputs and Outputs floating between power supply |

**Table—Comparison of VOA and COA.**

The pnp input "pair" floats between the upper and lower current sources, generating two equal and opposite signal currents. Darlington-connected transistors $Q_{17}$ and $Q_{18}$ and $Q_{21}$ and $Q_{34}$ form a differential pair and amplify these signal currents. The outputs of this combined input and gain stage, two differential currents in the collectors of $Q_{18}$ and $Q_{34}$, then feed an output stage. This stage, $Q_5$ through $Q_{12}$, provides additional current amplification, operating in a manner similar to commercially available transconductance amplifiers.

## Matching the current sources

To achieve low offset at the input terminals and improve dc stability, circuitry has been provided to match the upper and lower input stage current sources. A differential pair, $Q_{22}$ and $Q_{23}$, together with $Q_1$, $Q_2$ and $Q_{26}$ in a feedback loop, matches currents in $Q_2$ and $Q_{26}$. Moreover, by virtue of the matching achievable on a monolithic circuit, it matches currents in $Q_3$ and $Q_4$, and $Q_{27}$ and $Q_{28}$. A single external resistor sets up current in diode-connected transistor $Q_{33}$ and provides overall dc bias. In the prototype, the value of $R_7$ was ≈ 60 kΩ, giving total quiescent current of approximately 2 mA with a ±10V power supply. At this biasing level, the open-loop current gain was ≈ 5000.

$C_1$ and $C_2$, points where frequency compensation capacitors have good effects, have been brought out. For basic testing of the prototype, the unit was overcompensated; yet it still showed bandwidths in excess of 2 MHz in all of its controlled source realizations. It also showed load impedances from 1 to 10Ω. □

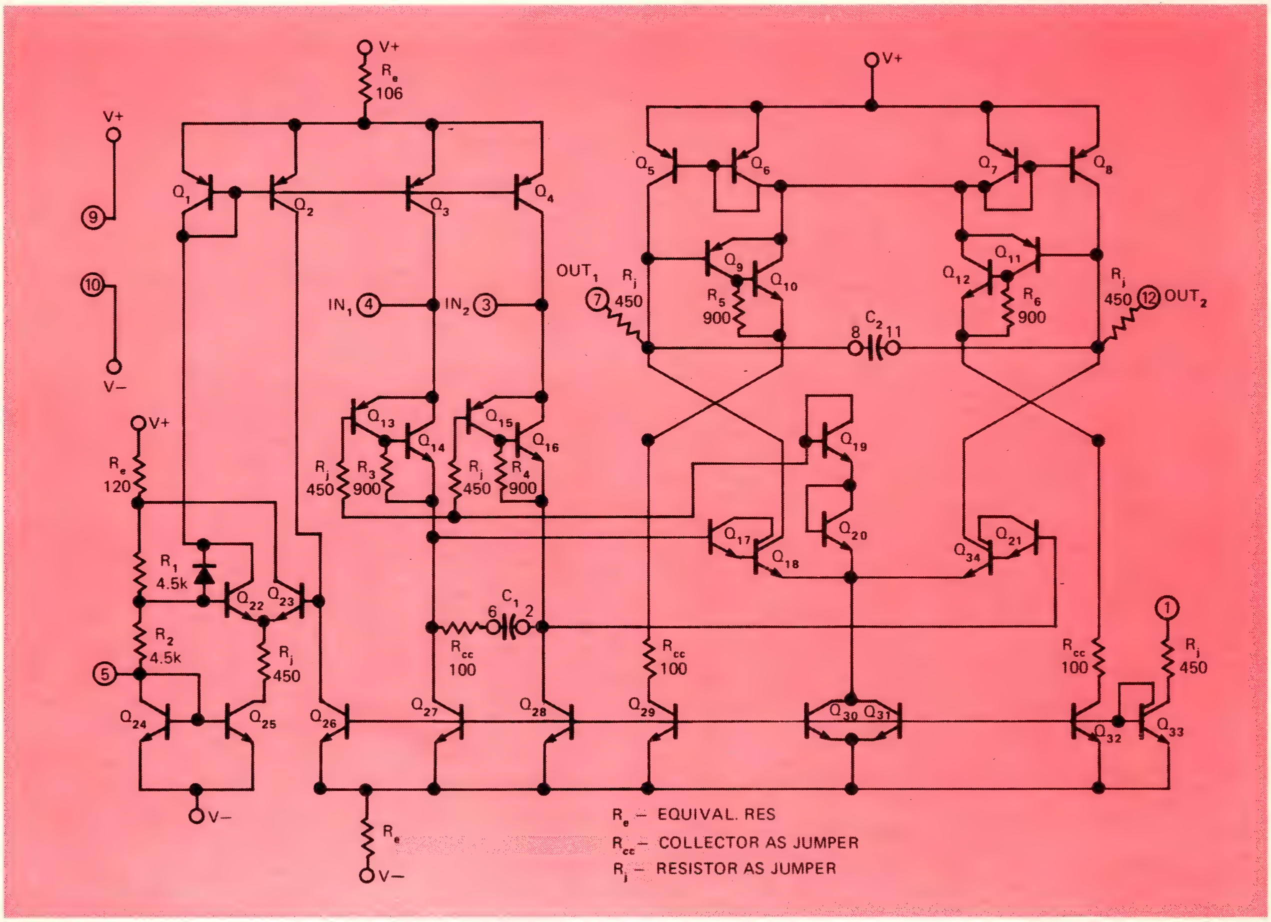

**Fig. 4—COA's monolithic implementation** is complete with crossover parasitics for optimized frequency compensation.

# LED's come into "VU"

**Gerald R. Stanley**

The age of the mechanical audio "VU" meter is destined to close. No longer must we tolerate the sluggish and fragile nature of an analog meter movement—not when responsive, reliable and inexpensive LED's are available. The Monochip technique greatly simplified the sequential display driver I created.

My design, a compact low-power display for a 7-element LED, uses a 15V regulated supply with LED's arranged in an ordered row and illuminated sequentially.

## Past problems, new solutions

This design eliminates common complaints about professional equipment:

- VU meters that do not indicate peak levels.
- Bulky VU meters that do not allow close placement in systems having a large number of channels. (In some systems, 16 or more channels must be within an operator's field of view.)
- Visibility of a black moving pointer that is too low to be sensible to an operator engrossed in the auditioning of a performance.

The LED drivers **(Fig. 5)** are all small npn devices with both collector terminals joined for minimum saturation resistance. However driver seven, a Darlington-coupled large npn device, does not fit this category. The availability of this device became apparent during layout and I seized it. A higher current (> 20 mA) output can be taken from the device, power supply permitting, if you desire to increase the visibility of the excessive audio level condition. ▭

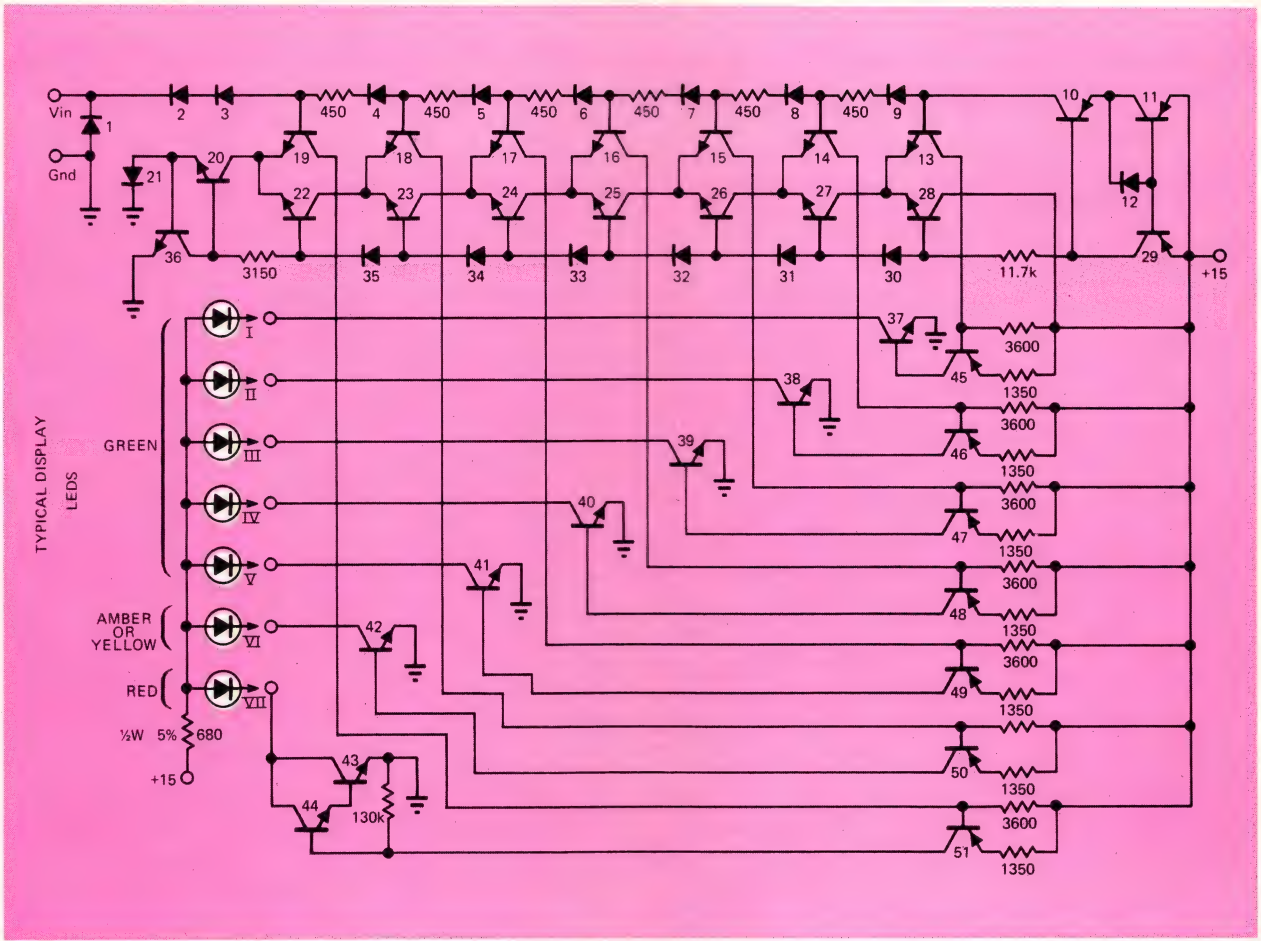

**Fig. 5—A natural candidate for integration:** The necessary matching and temperature tracking of the differential pairs ($Q_{13}$ to $Q_{19}$ and $Q_{22}$ to $Q_{28}$) and biasing elements ($Q_2$ to $Q_9$) are provided inherently on the Monochip. Current is diverted gradually from $Q_{28}$ to $Q_{22}$ causing each stage to turn on in succession. In this manner, a 'Jacob's ladder' display is provided.

# Combination lock requires memory and speed

**B. W. Glass**

Activated from an array of pushbutton switches greater than four (possibly a 10-button calculator keyboard), the security of this circuit is increased with two additional constraints. A *combination timer* is started as soon as the first correct button is pushed. The user then has a certain time to complete the sequence. If the sequence isn't completed on time, operation must again start from the beginning number. Choosing a wrong number causes the lock to be blocked for a specific time and triggers an optional alarm output.

## Let your fingers do the walking

If the correct first button is pushed **(Fig. 6)**,flip-flop 1 is set through $D_1$.

Setting flip-flop 1 reduces the collector potential of $Q_1$ to ground, enabling the gate created by $Q_{10}$. As the second correct button is pushed, $Q_{15}$ turns ON, $Q_{10}$ turns OFF, and flip-flop 2 is set. This sequence continues on through flip-flops 3 and 4. Once the last flip-flop is reached, the output terminal goes HIGH. This output may drive a power transistor or triac that, in turn, powers a solenoid.

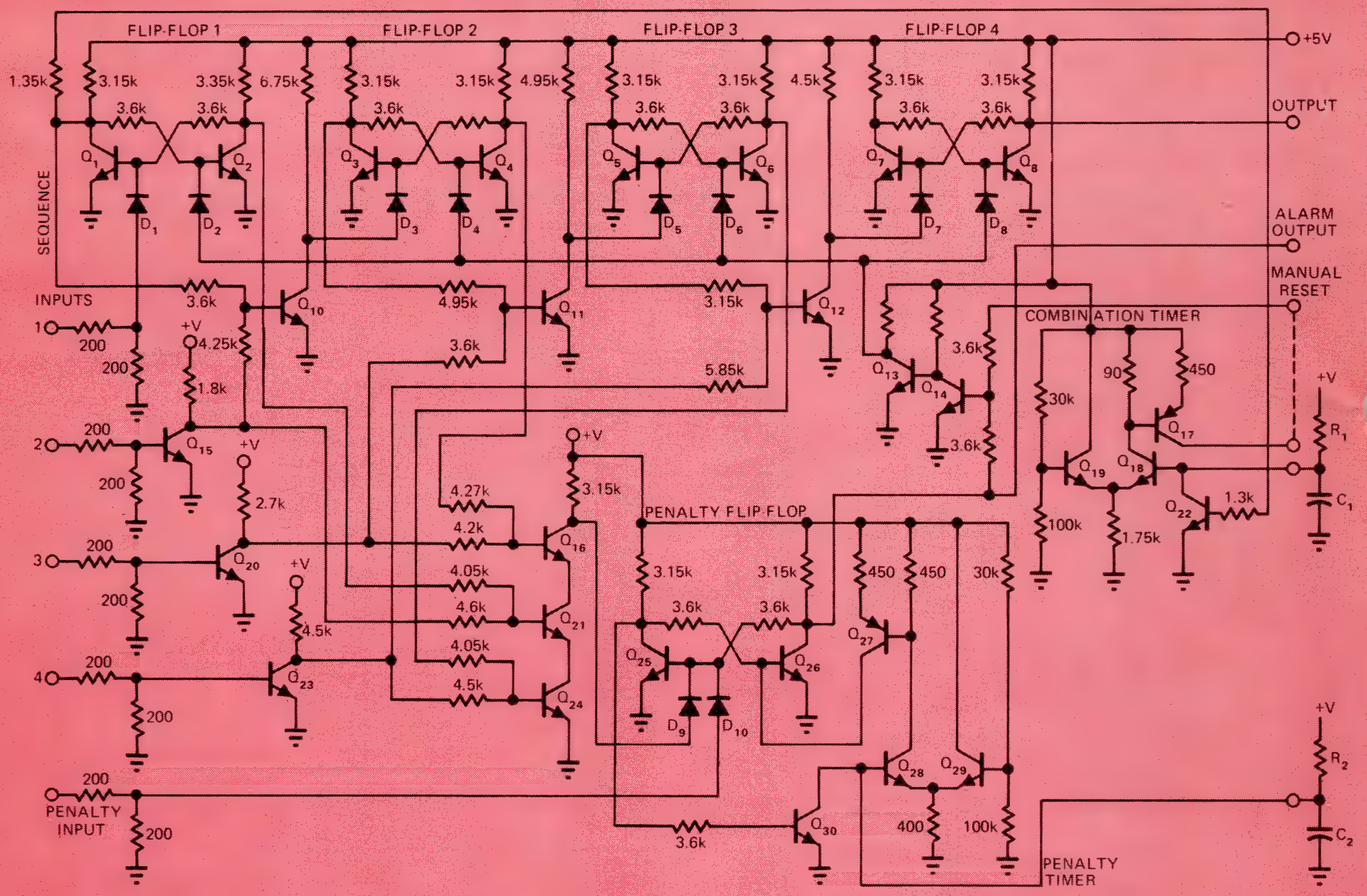

**Fig. 6—Pushing the wrong button** sets the penalty flip-flops through transistors $Q_{13}$ and $Q_{14}$. Simultaneously, the penalty timer starts, causing the lock to be blocked for a specific time.

Simultaneous with the setting of flip-flop 1, the combination timer is started through transistor $Q_{22}$. This transistor turns OFF, thus removing the short across external timing capacitor $C_1$, and allowing it to start charging through $R_1$. When $C_1$'s voltage reaches approximately 75% of the supply voltage (given by the 30 kΩ/100 kΩ resistor ratio), $Q_{18}$ turns ON, activating $Q_{17}$ and $Q_{14}$. $Q_{13}$ then turns OFF and resets all four flip-flops.

The total time allowed to press the sequence can be set (with the two external components) from one to at least 100 seconds. The lock can also be reset manually by connecting the manual reset terminal to +V. ☐

# Switching postregulator uses standard parts

**Robert Brown** and **Steve Hall**

Our Monochip design **(Fig. 7)** provides an inexpensive circuit which, when used with a standard regulator such as the μA 723, creates a switching regulator. This combination allows a high efficiency regulator to be placed directly on a card or, in the case of a dc-to-dc converter, provides independent voltage adjustment and regulation for multiple outputs. The IC itself provides timing, voltage-to-duty-cycle conversion, error amplification, current-limit sensing and drive to the power transistor.

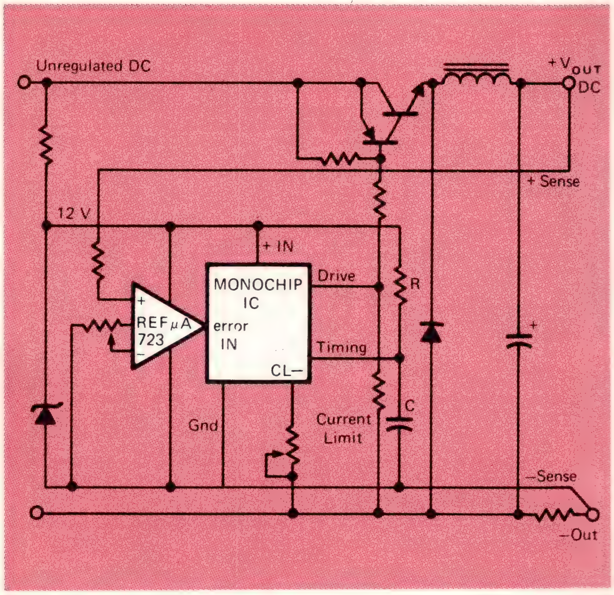

**Fig. 7—Combine the custom Monochip circuit** with a standard 723-type linear regulator and you get a high efficiency switching regulator. RC network determines switching frequency.

## Dual purpose feature added

The complete circuit diagram of the monochip is shown in **Fig. 8.** The ramp generator consists of a differential pair ($Q_6$, $Q_7$), biased at one-half the supply voltage, and an SCR-like reset circuit ($Q_1$, $Q_2$). As soon as external resistor R charges capacitor C to one-half of the supply voltage, $Q_6$ turns ON. This activates $Q_8$, which pumps current into the base of $Q_1$. Positive feedback into the base of $Q_2$ ( and back into the base of $Q_1$) causes the two transistors to turn ON rapidly, discharging C. When the voltage reaches approximately 0.8V, $Q_1$ and $Q_2$ turn OFF, and the charge cycle starts anew.

$Q_9$ buffers the resulting ramp waveform, which is fed to the base of $Q_{15}$, one input of the comparator. The second input, ($Q_{16}$), receives its signal from the voltage reference, and is divided down by a resistance ratio to make the error signal compatible with the output of a standard IC.

The output of the comparator is amplified and level-shifted through $Q_{10}$ and $Q_{11}$. The current-limit amplifier is a standard differential stage ($Q_{23}$, $Q_{24}$) with an emitter follower ($Q_{20}$).

One additional feature built into the chip, is that $Q_{19}$ and the terminal marked ON/OFF have a dual purpose. Connecting the ON/OFF pin to ground shuts off the regulator, while connecting a capacitor from this point to ground provides an initial (power-up) time delay that prevents overshoot. ▭

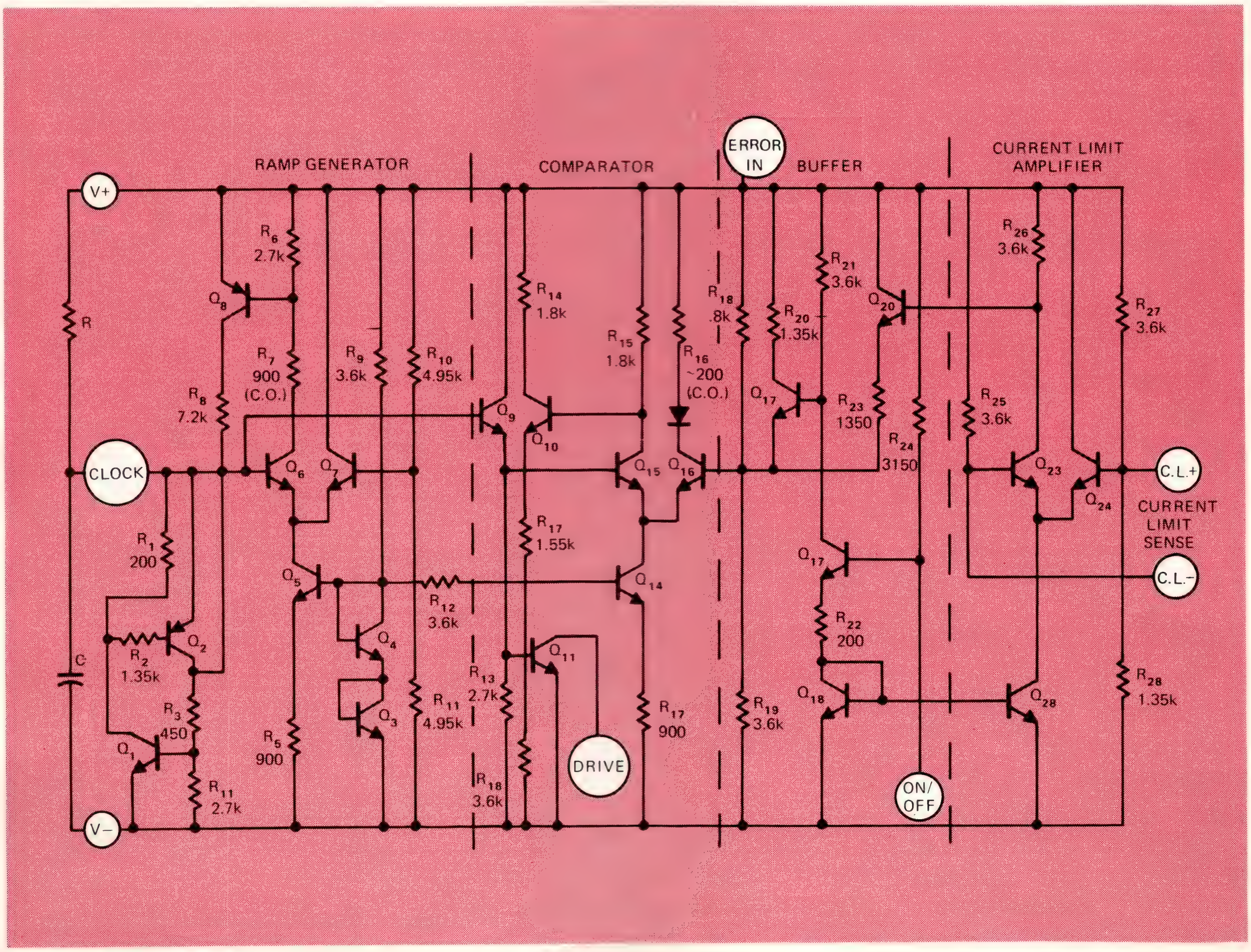

**Fig. 8—Timing voltage-to-duty-cycle conversion,** error amplification, current-limit sensing and power transistor drive are provided by this configuration of the Monochip's components.

# A STAR IS BORN TO SAVE SPACE

# api Series 1000 Edgewise Meters

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**STYLE**—Sculptured, crystal-clear window and molded black flange crisply define the dial for an appearance of modern engineered precision. No separate bezel is required.

**MOUNTING**—Both the 1015 and 1025 fit standard panel cutouts, yet the snap-in mounting is simpler than any other edgewise mounting method, saving you time and money.

**ACCURACY**—The unique flat d'Arsonval pivot-and-jewel mechanism provides 2% accuracy for vertical or horizontal scale orientations; and complies with ANSI C39.1 performance and C39.5 safety standards.

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# A programmable calculator for parallel impedance problems?

*It's not necessarily an overkill. You can save a lot of time and time means money. If the machine is there, why not use it?*

**William H. Smyers, Jr.**, Consultant

Programmable calculators, like dandelions, are springing up everywhere. They will soon be as common in the office as dictating machines, telephones and swivel chairs. The reason for their growing popularity? They can provide tremendous time savings in solving not only complex problems, but also relatively simple ones as well.

In view of their increasingly widespread use, today's designers should do two things. For those already using calculators, exchange of programs and techniques is essential. It is, after all, quicker to transpose someone else's already debugged program into the language of your own machine than it is to start from scratch. Also, you may stumble upon some programming techniques you can adapt, even if you must manipulate data a little differently in your calculator.

You should also become familiar with the characteristics of various makes and models. You may be quite satisfied with the Hewlett-Packard 9820 that you're presently using. But what do you do when you move on to a new position and find a Wang 600 on your desk?

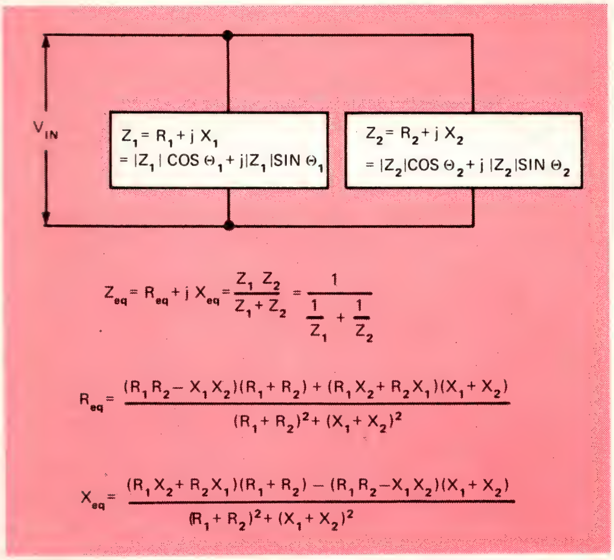
If you're not yet using programmable calculators, think ahead. Some day, your boss may ask you to recommend the type of machine the company should buy. If you're ready with an answer, you'll not only get the machine you want, you'll also score some points.

In light of this situation, we'll take another look at a simple problem. Calculating the parallel equivalent of two complex impedances is relatively easy and occurs quite frequently. This problem was discussed in the Dec. 5, 1973 issue of EDN ("New generation calculators slash circuit design costs" by Jack Frost). Let's extend the thoughts of that article, and explore the advantages of using a programmable calculator on this relatively simple problem. We will also examine a couple of programs that will solve the problem on a Wang 400, 500 or 600, and note the basic data manipulating method for these machines.

## When time means money, save it

The parallel impedance problem is summarized in **Fig. 1**. This figure is essentially the same as **Fig. 3** in the referenced article. Before proceeding, we must define the term *manipulation*. Each entry of a piece of data, each arithmetic operation, and each grouping of terms is considered a manipulation. On this basis, solving the equations for $R_{eq}$ and $X_{eq}$ involves about 70 manipulations.

Assuming that no pre-planning or special techniques are used, the time required to solve the problem on a slide rule, or nonprogrammable calculator having no polar-to-rectangular conversion key, should be roughly proportional to this figure. A few trials on sample problems leads one to the conclusion that a typical engineer might take around six minutes or more to obtain the correct answers when operating in such fashion. In this problem, making use of the similarity of some of the groups of terms will reduce the number of manipulations, the solution time and


$V_{IN}$
$Z_1 = R_1 + jX_1 = |Z_1| \cos\Theta_1 + j|Z_1| \sin\Theta_1$
$Z_2 = R_2 + jX_2 = |Z_2| \cos\Theta_2 + j|Z_2| \sin\Theta_2$

$$Z_{eq} = R_{eq} + jX_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}}$$

$$R_{eq} = \frac{(R_1R_2 - X_1X_2)(R_1 + R_2) + (R_1X_2 + R_2X_1)(X_1 + X_2)}{(R_1 + R_2)^2 + (X_1 + X_2)^2}$$

$$X_{eq} = \frac{(R_1X_2 + R_2X_1)(R_1 + R_2) - (R_1R_2 - X_1X_2)(X_1 + X_2)}{(R_1 + R_2)^2 + (X_1 + X_2)^2}$$

**Fig. 1—Two sizable formulas** represent the solution to the parallel impedance problem.

the number of expected errors. However, the time spent pre-planning must be counted also.

Let's say that it will take at least five minutes to solve the problem by hand. Remember, doing 70 manipulations without error is akin to having an error rate of less than 1.4%. Therefore, those of us that are less than 98.6% perfect in such tasks will want to recheck any answer we get.

Mr. Frost's article showed that a calculator having polar-to-rectangular conversion keys could yield a solution in about 25 steps. It suggested that a solution could be accomplished in about a minute. If the operator has run the problem often enough to have memorized the steps, this timing is realistic. However, if you must reason out the sequence as you go, assume a solution time more on the order of 90 seconds.

It should be noted that we have considered the entry of a value such as $R_1$ to be a single step although it will require a separate key stroke for each digit, decimal point, etc. In any case, we can see that 25 steps instead of 70, or one and one-half minutes instead of five represents something in the neighborhood of 70% time and error saving. If this type of problem arises often, a considerable saving can result. However, 25 steps is still quite a bit to do consistently without error (it requires less than a 4% error rate, so those of us who are only 96% perfect will still want to recheck).

The programmed solution to the problem, however, is just about the ultimate in simplicity and speed. There are really only four steps or manipulations. If you count hitting the "go" key after each data entry as a step, then it might be argued that it is an 8-step procedure. In any case, the actual entries are simply:

$$R_1, \text{go}, X_1, \text{go}, R_2, \text{go}, X_2, \text{go}.$$

The answers for $R_{eq}$ and $X_{eq}$ will be printed back immediately. This process takes about 10-15 seconds, and more than likely can be considered to be essentially error free. The programmed solution, in any case, is something more than a 95% time and error savings over the hand method, and at least a 75% savings over the hand method that uses polar conversion keys. The engineer who spends any significant amount of his time solving problems analogous to this example can't help but save time, and hence money for his employer, by using a programmable calculator.

It must be conceded that the example used is a particularly lucrative one for programming. Seventy manipulations performed on only four pieces of raw data means that a lot of work can be done by a program. If your problem involves adding 70 different numbers together, inputting the raw data is the major part of your work. Under these conditions, very little savings will be realized by using a programmed solution. However, if you have to count the number of data entries, find an average and a standard deviation, etc., the programmed approach is the way to go.

## Getting to know the Wang calculator

The programs to be discussed will solve the parallel impedance problem on a Wang 400, 500 or 600 calculator. Specifically, they were written for a particular 600 machine that had a strip printer, but did not have hard-wired or ROM polar conversion keys. However, the equivalent capability can be obtained by a single key access to a subroutine.

There is just one display on the Wang 600 calculator, and any number you enter from the keyboard appears in that display. Keystroke command operations that involve just one number, such as sine or log, are performed on the number in the display. The result appears in the

PROGRAM "A"

| STEP NUMBER | KEYSTROKE COMMAND | COMMENTS |
|---|---|---|
| 0 | ST 0 | STORES $R_1$ IN REGISTERS 0, 5 AND 6 |
| 1 | ST 5 | (STARTED WITH $R_1$ IN DISPLAY) |
| 2 | ST 6 | |
| 3 | STOP | STOPS FOR OPERATOR TO ENTER $X_1$ IN DISPLAY |
| 4 | ST 1 | STORES $X_1$ IN REGISTERS 1, 4 AND 8 |
| 5 | ST 4 | |
| 6 | ST 8 | |
| 7 | STOP | STOPS FOR $R_2$ |
| 8 | ST 2 | |
| 9 | + 5 | ADDS $R_2$ TO REGISTER 5 (GETS $R_1 + R_2$ IN REGISTER 5 AND IN DISPLAY) |
| 10 | ST 9 | STORES $R_1 + R_2$ IN REGISTER 9 |
| 11 | $X^2$ | SQUARES DISPLAY (GETS $(R_1 + R_2)^2$ IN DISPLAY) |
| 12 | ST 7 | |
| 13 | RE 2 | RECALLS $R_2$ (REGISTER 2) |
| 14 | X 6 | GETS $R_2R_1$ IN REGISTER 6 |
| 15 | STOP | $X_2$ |
| 16 | ST 3 | |
| 17 | X 8 | $X_2X_1$ IN REGISTER 8 |
| 18 | – 6 | $R_1R_2 - X_1X_2$ IN REGISTER 6 AND DISPLAY |
| 19 | X 5 | GETS $(R_1R_2 - X_1X_2)(R_1 + R_2)$ IN REGISTER 5 |
| 20 | RE 3 | |
| 21 | X 0 | GETS $R_1X_2$ IN REGISTER 0 |
| 22 | RE 2 | $R_2$ |
| 23 | X 1 | $R_2X_1$ |
| 24 | + 0 | $(R_1X_2 + R_2X_1)$ |
| 25 | X 9 | GETS $(R_1 + R_2)(R_1X_2 + R_2X_1)$ IN REGISTER 9 |
| 26 | RE 3 | $X_2$ |
| 27 | + 4 | $X_2 + X_1$ |
| 28 | X 6 | $(R_1R_2 - X_1X_2)(X_2 + X_1)$ |
| 29 | – 9 | GETS $(R_1 + R_2)(R_1X_2 + R_2X_1) - (R_1R_2 - X_1X_2)(X_1 + X_2)$ IN REGISTER 9 |
| 30 | RE 4 | $X_2 + X_1$ |
| 31 | X 0 | $(R_1X_2 + R_2X_1)(X_1 + X_2)$ |
| 32 | + 5 | GETS $(R_1X_2 + R_2X_1)(X_1 + X_2) + (R_1R_2 - X_1X_2)(R_1 + R_2)$ IN REGISTER 5 |
| 33 | RE 4 | |
| 34 | $X^2$ | |
| 35 | + 7 | $(X_1 + X_2)^2 + (R_1 + R_2)^2$ |
| 36 | ÷ 5 | GETS $R_{eq}$ IN DISPLAY AND REGISTER 5 |
| 37 | PRINT | PRINTS $R_{eq}$ TO 10 DECIMAL |
| 38 | E 10 | PLACES |
| 39 | RE 7 | |
| 40 | ÷ 9 | GETS $X_{eq}$ IN DISPLAY AND REGISTER 9 |
| 41 | PRINT | PRINTS $X_{eq}$ TO 10 DECIMAL PLACES |
| 42 | T 10 | |
| 43 | STOP | |

**Fig. 2—Program A is a short, fast solution** for $R_{eq}$ and $X_{eq}$, using the equations of **Fig. 1**.

display in place of the original number.

There are 16 registers in which arithmetic can be performed. Arithmetic operations involving two numbers require only a single program step. As an example, command ÷8 will divide the number in register 8 by the number that is in the display. In addition to appearing in register 8, the result will appear in the display, where it is ready to be part of some subsequent operation. Unless provision for storing has been made, the number that was previously in the display will be lost.

Of the 16 arithmetic registers, 14 and 15 are scratch pad registers. They are handier to use since they require only a single physical key motion, such as ÷15. The command ÷12, on the other hand, requires both the ÷ select key and the 12 key to be pushed down.

| STEP NUMBER | KEYSTROKE COMMAND | COMMENTS | |
|---|---|---|---|
| | | PROGRAM "B" | |
| 0 | F3 | GO TO SUBR. F3 | |
| 1 | ST 1 | STORE $R_e(1/Z_1)$(LEFT IN DISPLAY BY F2 OF F4 ( F3) IN REGISTER 1 | |
| 2 | RE 14 | RECALL $Im(1/Z_1)$(LEFT IN REGISTER 14 BY F2 OF F4 OF F3) | |
| 3 | ST 2 | STORE $Im(1/Z_1)$ IN REGISTER 2 | |
| 4 | STOP | STOP FOR OPERATOR TO ENTER $R_2$ | |
| 5 | F3 | GO TO SUBR. F3 (SAME AS STEP 0, BUT FOR $R_2+X_2$) | |
| 6 | RE 2 | $Im(1/Z_1)$ | |
| 7 | + 14 | GETS $Im(1/Z_1)+Im(1/Z_2)=Im(1/Z_{eq})$ IN REGISTER 14 | |
| 8 | RE 1 | $Re(1/Z_1)$ | |
| 9 | + 15 | GETS $Re(1/Z_1)+Re(1/Z_2)=Re(1/Z_{eq})$ IN REGISTER 15 | |
| 10 | F4 | GO TO SUBR. F4 (FINDS $1/Z_{eq}$ IN POLAR FORM. INVERTS THAT TO FIND $Z_{eq}$ AND CONVERTS THAT TO RECTANGULAR $R_{eq}$ AND $X_{eq}$) | |
| 11 | RE 15 | | |
| 12 | PRINT | PRINT $R_{eq}$ TO 10 DECIMAL PLACES | |
| 13 | E 10 | | |
| 14 | RE 14 | | |
| 15 | PRINT | PRINT $X_{eq}$ TO 10 DECIMAL PLACES | |
| 16 | T 10 | | |
| 17 | STOP | | |
| 18 | MARK | IDENTIFIES AS SUBR. F1 | SUBR. F1<br>CONVERTS RECTANGULAR TO POLAR.<br>STARTS WITH R IN REGISTER 15 AND X IN REGISTER 14 AND ENDS WITH \|Z\| IN REGISTER 15 AND Θ IN REGISTER 14 AND IN DISPLAY. |
| 19 | F1 | | |
| 20 | RE 14 | RECALL X | |
| 21 | $X^2$ | $X^2$ | |
| 22 | C 15 | EXCHANGE DISPLAY AND REGISTER 15 (GETS $X^2$ IN REGISTER 15 AND R IN DISPLAY) | |
| 23 | $X^2$ | $R^2$ | |
| 24 | + 15 | $X^2+R^2$ IN REGISTER 15 AND DISPLAY | |
| 25 | $\sqrt{X}$ | $\sqrt{X^2+R^2}=\|Z\|$ | |
| 26 | ST 15 | \|Z\| IN REGISTER 15 | |
| 27 | ÷14 | X/\|Z\| | |
| 28 | $SIN^{-1}$ | ARC SIN (X/\|Z\|) = Θ | |
| 29 | ST 14 | Θ IN 14 | |
| 30 | RETURN | RETURN TO STEP AFTER THE ONE THAT CALLED THIS SUBR. | |
| 31 | MARK | IDENTIFY F2 | SUBR. F2:<br>CONVERTS POLAR TO RECTANGULAR.<br>(STARTS WITH \|Z\| IN REGISTER 15 AND Θ IN REGISTER 14 AND ENDS WITH R IN REGISTER 15 AND DISPLAY AND X IN REGISTER 14,) |
| 32 | F2 | | |
| 33 | RE 15 | \|Z\| | |
| 34 | $X^2$ | $\|Z\|^2$ | |
| 35 | C 15 | $\|Z\|^2$ IN REGISTER 15, \|Z\| IN DISPLAY | |
| 36 | C 14 | \|Z\| IN REGISTER 14, Θ IN DISPLAY | |
| 37 | SIN | SIN Θ | |
| 38 | X 14 | \|Z\| SIN Θ = X | |
| 39 | $X^2$ | $X^2$ | |
| 40 | − 15 | $\|Z\|^2-X^2=R^2$ | |
| 41 | $\sqrt{X}$ | R | |
| 42 | ST 15 | R IN REGISTER 15 AND DISPLAY | |
| 43 | RETURN | | SUBR. F3:<br>STARTS WITH R IN DISPLAY; ENTERS X, THEN INVERTS VIA F4 |
| 44 | MARK | IDENTIFY F3 | |
| 45 | F3 | | |
| 46 | ST 15 | STORE R IN REGISTER 15 | |
| 47 | STOP | STOP FOR OPERATOR ENTRY OF X | |
| 48 | ST 14 | X IN 14 | |
| 49 | F4 | GO TO SUBR. F4 | |
| 50 | RETURN | | SUBR. F4:<br>R IN REGISTER 15 AND X IN REGISTER 14 AND CONVERTS THOSE TO POLAR VIA F1; INVERTS POLAR VECTOR AND THEN CONVERTS THAT BACK TO RECTANGULAR COORDINATES VIA F2, ENDING WITH Im (1/Z) IN REGISTER 14 AND Re( 1/Z) IN REGISTER 15 AND IN DISPLAY |
| 51 | MARK | IDENTIFY F4 | |
| 52 | F4 | | |
| 53 | F1 | GO TO F1 | |
| 54 | CHS | CHANGE SIGN OF DISPLAY | |
| 55 | ST 14 | −Θ IN REGISTER 14 | |
| 56 | RE 15 | \|Z\| | |
| 57 | 1/X | 1/\|Z\| | |
| 58 | ST 15 | | |
| 59 | F2 | GO TO F2 | |
| 60 | RETURN | | |

**Fig. 3—Making use of general purpose subroutines,** program B is a longer, slower solution using fewer storage registers.

The above description may only cover about 1% of the Wang 600 instruction manual, but it probably explains 75% of the program steps ever written for the machine.

The Wang system is extremely efficient, in terms of doing a lot of mathematics in the least number of program steps. But it is probably not quite as natural to program as are calculators like the Monroe 1880, Tektronix TEK 31 or the HP 9820. You program these machines sequentially, the same as the algebraic equations are written.

## When speed is what you need...

Program A, along with explanatory comments (**Fig. 2**), solves the complex impedance problem by using the two equations of **Fig. 1**. It does not follow the terms of those equations in order of their appearance, however. Instead, the program uses several techniques, which make it short and fast.

Once a number is in the display, it may be stored on a one register/step basis. For instance, the program starts with $R_1$ in the display. The first three steps immediately store $R_1$ in registers 0, 5 and 6. In step 21, register 0 will become $R_1X_2$, and still later $(R_1X_2+R_2X_1)$ in step 24. By step 31, register 0 contains $(R_1X_2+R_2X_1)(X_1+X_2)$. Register 5 holds the term $R_1+R_2$ in step 9, and winds up as $(R_1+R_2)(R_1R_2-X_1X_2)$ in step 19.

After the process of operating on a register, the result of that operation is in the display as well. A single step can then be used to make that quantity operate on some other register. As an example, $X_2$ is put into the display during the stop at step 15. During the next four operations, no steps are wasted recalling quantities. After storing $X_2$ in register 3 in step 16, we can, in the next step, multiply it by register 8 to get $X_1X_2$ in both register 8 and the display. This quantity is subtracted from register 6, in step 18, to get $(R_1R_2-X_1X_2)$. We then multiply by register 5 to get $(R_1+R_2)(R_1R_2-X_1X_2)$ in step 19.

Techniques such as these are quite economical for both compute time and program memory. If you slightly modify the program to run on already stored input data, and to skip the printing steps, it will run in about 110 msec. Program A then can probably be used as an iterating subroutine in some other main program, without sacrificing speed.

The program was not born 44 steps in length. By selective pruning and re-arranging, it was reduced from 60 steps. If you have plenty of program memory or are going to use the program by itself, and infrequently at that, then 44 steps instead of 60 is immaterial. However, if your calculator only has 200 steps of memory, and you want to put several similar programs in memory simultaneously, the 25% savings in program length may make the difference between fitting and overflowing.

Two other angles about the program length should be noted. The short length is achieved by using up 10 arithmetic registers. If, as a result of your main program, such registers are in short supply in your calculator, then program A may not be a very good choice for a subroutine.

Secondly, calculators that use straight algebraic programming of equations seem to require significantly more program steps to do the same job. Some sample first-cut programs written for this type of machine contain 100 to 145 steps. Naturally, some pruning and refining can shorten these programs. Although it is possible that someone familiar with analagous techniques for these machines could effect a drastic reduction, it is not probable. When you decide to program just as the equations are written, the only leeway for variations is re-arrangement of the equations.

## Free up registers with subroutines

Program B (**Fig. 3**) attacks the problem by employing subroutines that use essentially the same polar conversion procedure as outlined in Mr. Frost's article. For the Wang 600, these conversions, written as subroutines, are accessible by a single keystroke or program step. Steps 18 to 30 are a rectangular-to-polar conversion subroutine. To use it, you must have previously put your rectangular coordinates $R_i$ and $X_i$ in registers 15 and 14, respectively. A single step command, F1 in this case, will yield the polar magnitude, $|Z_i|$ in 15 and the polar angle, $\Theta$ in 14.

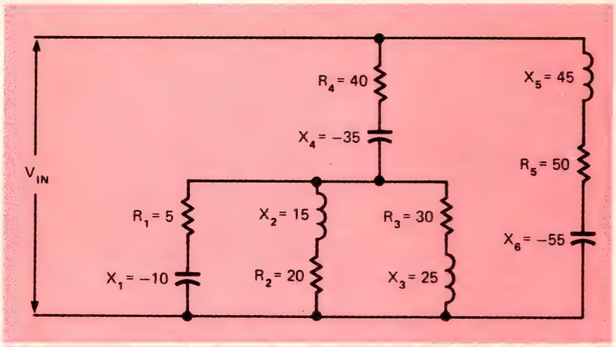
Subroutine F2, in steps 31-43, performs the reverse operation. Subroutine F4 (steps 51-60) uses the first two subroutines to obtain the inverse of a set of rectangular coordinates by first converting them to polar. It inverts the polar vector, getting $1/|Z_i|$ and $-\Theta$, and finally converts them back to rectangular coordinates. The last subroutine, F3, calls up the inversion routine, F4, and enters the $X_i$ part of the input data.

The main part of the program, then, only takes place in steps 0 to 17. Note that the program starts with $R_1$ already in the display. The initial program action involves calling subroutine F3, and storing $R_1$ in register 15 at step 46.

Program B has some advantages. You may want subroutines F1, F2 and F4 in your memory for other reasons—single key commands for hand calculations, or subroutines for direct access from other main programs. If so, then the additional program memory necessary for the complex impedance problem is only steps 0 to 17 and 44 to 50, a total of 25 steps. While it's true that shorter subroutines can be written for polar conversion, these three (F1, F2 and F4) have the advantage of utilizing only the scratch pad registers, 14 and 15. They can, therefore, be used in most main programs without disturbing the data in any of the other registers.

In fact, program B employs only these two registers plus registers 1 and 2. It is, thus, relatively easy to use as a complete subroutine, although the program is pretty slow. Because it has to search for subroutines 11 times, it takes about 1.7 seconds to compute the answer. For many applications, this time would be most acceptable. However, for some trial and error applications, where a complex impedance subroutine might have to be called 1000 times during the solution of the main problem, program A might be a better choice.

You can use both of the programs for some network problems. With program B, for example, the answers for $R_{eq}$ and $X_{eq}$ end up in registers 15 and 14, respectively. They can be recalled, as part of an adjacent parallel or series impedance, to work branch by branch through the network.



| OPERATOR KEYSTROKES (EACH KEYSTROKE IS UNDERLINED) | COMMENTS |
|---|---|
| PRIME | READY TO START THE PARALLEL IMPEDANCE PROGRAM |
| 5 GO<br>1 0 CHS GO<br>2 0 GO<br>1 5 GO | PUTS $R_1$ AND $X_1$ IN PARALLEL WITH $R_2$ AND $X_2$ LEAVING $R_{eq}$ IN REGISTER 15 AND $X_{eq}$ IN REGISTER 14. DISREGARD PRINTOUT AT THIS POINT |
| PRIME | READY FOR ANOTHER PARALLEL BRANCH |
| RE15 GO | USES PREVIOUS $R_{eq}$ |
| RE 14 GO | USES PREVIOUS $X_{eq}$ |
| 3 0 GO<br>2 5 GO | PUTS $R_3$ AND $X_3$ IN PARALLEL WITH PREVIOUS RESULTS. DISREGARD THIS PRINTOUT TOO. |
| 4 0 +15<br>3 5 −14 | PUTS $R_4$ AND $X_4$ IN SERIES WITH THE COMBINATION SO FAR. |
| PRIME | READY FOR ONE MORE PARALLEL BRANCH |
| RE 15 GO<br>RE 14 GO<br>5 0 GO<br>4 5 ST14 5 5 −14 GO | PUTS $R_5 + j(X_5 + X_6)$ IN PARALLEL WITH THE REST. PRINTOUT;<br>$R_{eq}$ = 26.54450689<br>$X_{eq}$=-11.49862981 |

**Fig. 4—Program B works branch by branch** through the circuit to find the equivalent impedance of the network.

The impedance of the group of elements in **Fig. 4** can be solved quite quickly using program B. Obtaining the equivalent complex impedance of this network requires 45 keystrokes, which result from about 17 steps of thought process. The whole procedure takes about two minutes. This time is rather attractive, when you consider that you can do it on a machine with only 60 steps of memory. Surely, we can all remember the long hours we spent looking for an obvious error in a problem no more complex than this.

## On this rock, I will build

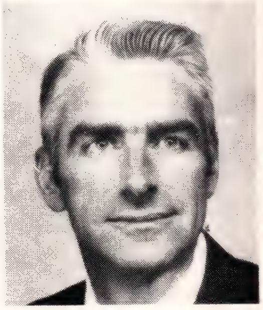
Short programs can form a foundation of subroutines for a hierarchy of programs that are used to solve increasingly complex problems. Let's consider some simple extensions of our results so far.

How about adding a subroutine to calculate the inductive and capacitive reactance for a given frequency? Given this luxury, the values of inductance and capacitance, rather than reactance values, can become a program input. A routine could be added that would solve for the current through, or voltage across, a particular part of the circuit, instead of computing the circuit's overall impedance.

Supervisory programs could obtain the data necessary to plot a circuit frequency response, determine the frequency of peak response and optimization procedures.

If you do any significant amount of numerical figuring, then the day will soon come when you'll have a programmable calculator right on your desk; not on a table in the middle of the engineering department or in a secured room up in the accounting department. Keep informed on these machines: what they can do and how they do it. Programmable calculators get more attractive with every new product release that comes down the pike. □

## Author's biography



**Bill Smyers** is an engineering and financial consultant in Wethersfield, CT. After receiving his BSME from Yale and his MSAE from Case Inst. of Technology, he worked extensively in the fields of fluid systems and components, automatic control systems, vibration and noise, machine tools, waste disposal, and plastic injection molding machines. Formerly Chief Research Engineer for New Britain Machine Co., he has nine patents, and is a registered Professional Engineer.

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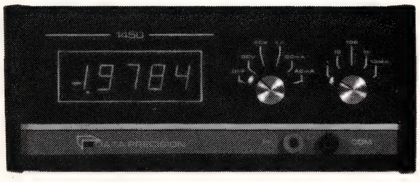

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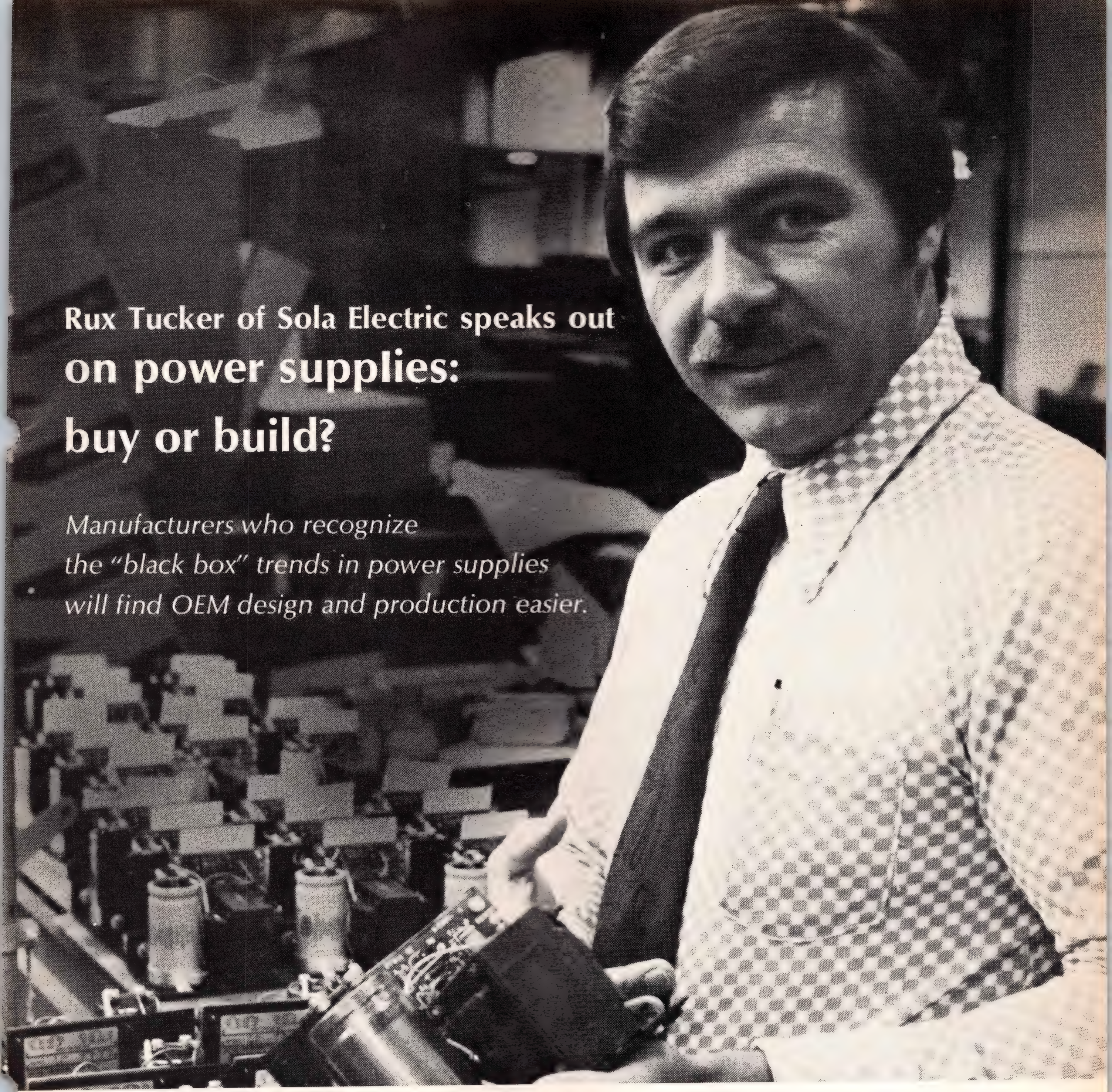
### Rux Tucker of Sola Electric speaks out

# on power supplies: buy or build?

*Manufacturers who recognize the "black box" trends in power supplies will find OEM design and production easier.*



**Standard power supplies account for only about 10%** of the U.S. power supply industry's total sales.

For many electronic OEM's, the traditional custom-designed power supply is turning out to be a costly and wasteful anachronism. Why? Because of the relatively new and fast-growing selection of standardized off-the-shelf (OTS) power supplies. These supplies cut down the component costs and inventories. They save valuable design engineering time for more important work. And they help the OEM's products get built and shipped faster.

Historically, the concept of custom-designed power supplies lies in the lack of commonality among the systems being designed. Each new design was considered unique, or at least so complex that it was simply impossible to think of satisfying all of its requirements with a standardized power supply.

**Those companies that can learn to think of power supplies as another "black box" component are the ones who will enjoy the benefits.**

What must be recognized is that during the last five years, certain trends have begun to reshape the power supply industry. Now these trends must reshape the thinking of engineering and design management as well. How did this happen? Let's look at the five major reasons.

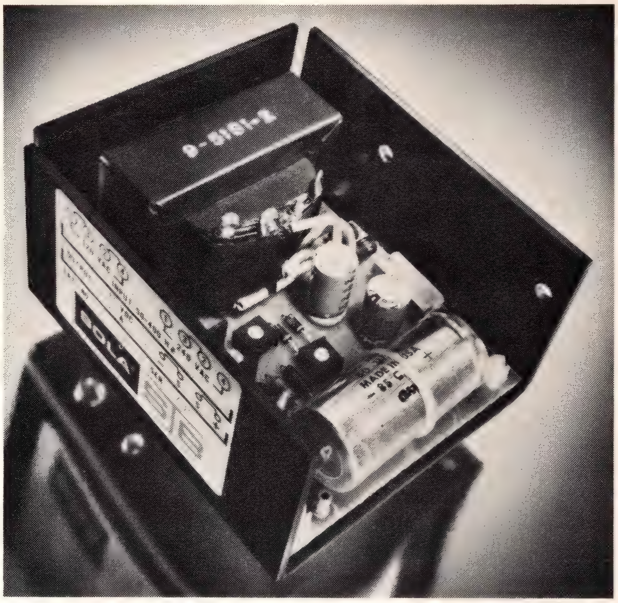
- Power supplies moved toward lower voltages. IC technology encouraged (if not forced) this move. It's a move that is still underway as we head for higher densities and lower breakdown voltages.
- Minicomputers demanded higher efficiency power supplies in smaller sizes.
- Product liability scares and new OSHA requirements prompted many manufacturers toward UL listing.
- Fewer outputs are needed. Five years ago power supplies commonly sported 10 to 14 outputs. Now, mainly due to IC compatibility, we deal in only three or four outputs—typically 5V dc with ±12 or ±15V dc.
- Logic (such as automatic sequencing) is being taken out of the power supply and put into the surrounding circuitry. There is no need to include them in the supply. The logic functions have already graduated to the status of black box components and are readily available in chip form.

These trends are all symptoms of the increasing commonality among the high-volume applications for power supplies. Together, they've established the kind of standards that inevitably result in practical, off-the-shelf designs. First to emerge were 30, 60 and 120W supplies in 5, 12, 15, 24 and 48V models. Recently we've seen the advent of miniature low-power supplies packaged in smart modular form. These are now becoming broadly available from electronic distributors. In the near future the trend toward logic voltages will generate more OTS units in the 4 to 5V range.

**The basic selection of standardized power supplies can usually be obtained in 48 hours or less from local electronic distributors. You normally need a minimum of 16 weeks for delivery of custom-built power supplies.**

The rapid growth of OTS designs, and their ready availability, means there are more and more applications where custom power supplies are used that should take advantage of the benefits that OTS units offer. Standard power supplies now account for only about 10% of total sales in the U.S. power supply industry. Yet time and again houses involved in power supplies see cases where standard OTS units can easily be substituted for the more costly custom designs.

This usually happens when the designer gave little or no consideration to the power supply until the last minute. It is a common occurrence with computers, some process controls and medical instrumentation. The power supply is not considered early enough in the design process. Engineering does not leave enough space to accommodate a standard power supply with sufficient total power capabilities. The result is a crash program to beat the state-of-the-art on power supply size and efficiency. This usually leads to a product that operates with a surface temperature much higher than desired...or one that has questionable field reliability.



**Typical off-the-shelf power supplies,** such as this 24V dc, 6A unit, are becoming broadly available from electronic distributors.

**For the designer, going the OTS route usually means designing to avoid extremes.**

Too often, power supplies are specified for capabilities far in excess of what they will encounter. Or they may be specified in such a way that they will far outlast the anticipated life of the equipment. In many of these cases, OTS units would be thoroughly adequate—and much more practical. The designer need only write realistic specs to understand this. In other cases, OTS units with some minor modifications will satisfy design needs, and still cut about 75% off the development lead time of a custom design.

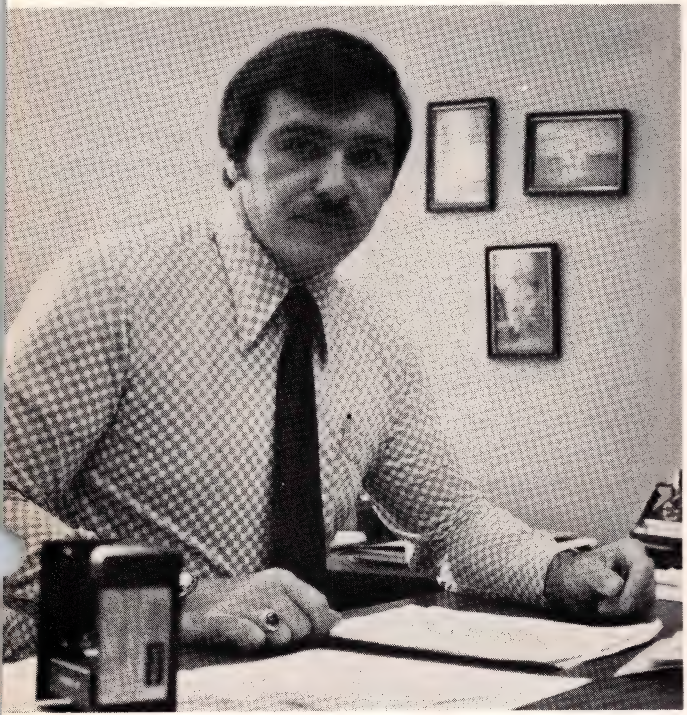
This, in fact, underscores a major fallacy in the classic argument for custom-built supplies. Buyers claim that the custom approach is the only way to avoid paying for extra features—the "Give me exactly what I want and only what I want" syndrome. That sounds good in theory. However, in practice, the designer invariably builds a "margin of safety" into his specs; a margin that usually is unnecessary but adds significantly to the cost and complexity of the device. The buyer still winds up paying extra for a lot of needless features.

**The major drawback to the designer thinking about standardized, off-the-shelf power supplies is that he is very likely to run into ambiguous, fragmented, unstandardized and sometimes omitted data.**

While the products are "standardized," subtle differences still exist between individual items. And these differences don't always show up in the manufacturers' data sheets.

For example, maximum temperature and maximum current are two key specs in power supplies. However, they do not always coincide, even though the spec sheet gives that impression. A manufacturer's data sheet may identify a power supply as a 5V, 12A unit with a top operating ambient of 75° C. Actual operation may show that the ambient must be held below 40° C in order to get the full 12A output.

When the line voltage drops below nominal, can you still get the maximum rated output? Since line power falls below nominal quite often these days this could turn out to be a real problem, one that doesn't show up until the product is in the field.



**Too often, power supplies are specified** for capabilities far in excess of what they will encounter.

Another key spec is response time, or "transient response." Does this mean recovery time limitations to reach the regulation envelope? Or time taken to reach full steady-state values? Or is it the time taken for the response to start? Data sheets don't always make this clear. Such semantic difficulties can and do cause real problems.

**In complete fairness, it should be noted that standard OTS power supplies are not always appropriate.**

Two situations in particular exist where a custom supply is still the better choice. The first is the result of the trends that led to the standardization of power supplies. These caused OTS designs to be best suited for minicomputers, office equipment and other "white collar" applications. They are not normally "hardened" against in-plant environments where heat, humidity, airborne contaminents and other hostile elements are common.

Consequently, power supplies sought for the majority of factory applications will be custom-built devices. Supplies for numerical machine-tool controls and process controls cannot be hidden in a clean room. They need special heat-sinking arrangements; tougher components, such as metal-can semiconductors; larger insulators; and computer-grade capacitors. OTS power supplies usually cannot satisfy these requirements.

This same consideration holds true for highly specialized laboratory type power supplies needing unique combinations of characteristics. Most of these are one-of-a-kind designs that will never be found on any distributor's shelf.

The quantity of power supplies needed determines the second important situation. If the OEM delivery requirement is less than 300 pieces a month, the OTS power supply will probably be the least costly. However, if the delivery schedule calls for more than 600 pieces/month—and the specs aren't outlandishly tight—the custom unit would be the way to go. In that gray area between 300 to 600/month, other specs and requirements make the difference. Thus, bids on both custom and OTS devices are then advisable for closer comparison.

These numbers sound good, but where did they come from? First, the custom power supply buyer must spend an average of $10,000 to $20,000 for design and prototype development prior to any production. Obviously, it takes a sizeable production run to amortize a development cost of that magnitude. Buying OTS power supplies does not penalize smaller quantity orders with such an investment.

A learning curve also applies to power supply production. Labor costs start to flatten out as production runs exceed 1500-pieces. Manufacturers operating above this level to produce two or three months deliveries in one run greatly increase their efficiency. Below that level, labor costs increase, so the custom supply starts to cost more than an alternative OTS unit. Exactly where

**Half-rack CVDC modular power supply,** being an OTS unit, does not penalize small quantity buyer with prototype development costs.

that break-even point lies can be determined only when precise specs are established. This generally falls somewhere above 300 pieces/month.

---

**At current prices for materials and labor, off-the-shelf power supplies generally cost anywhere from 60¢ to $1.25/watt in quantities to 100. Above 100 the price drops off gradually. Prices for custom units are likely to be considerably higher in small quantities.**

---

Thus, instances exist where special components are absolutely mandatory, or where purchase quantity permits high-efficiency production of custom devices. Nevertheless, it is pointless to waste money and valuable OEM engineering time designing something that in most cases has already been designed as well as the state-of-the-art will allow; proven over and over again in actual working applications; and is readily available as a standard, off-the-shelf "black box" module from your nearby electronics distributor. □

### Who is Rux Tucker?

**Rux Tucker** is marketing manager of electronic products for Sola Electric Div. of Sola Basic Industries in Elk Grove Village, IL. He is responsible for market penetration and product application for products sold through electronic distributors and to electronic OEM's. Rux received his EE degree from the University of Illinois and an MBA from Loyola University. Outside interests include tennis, skiing and photography.

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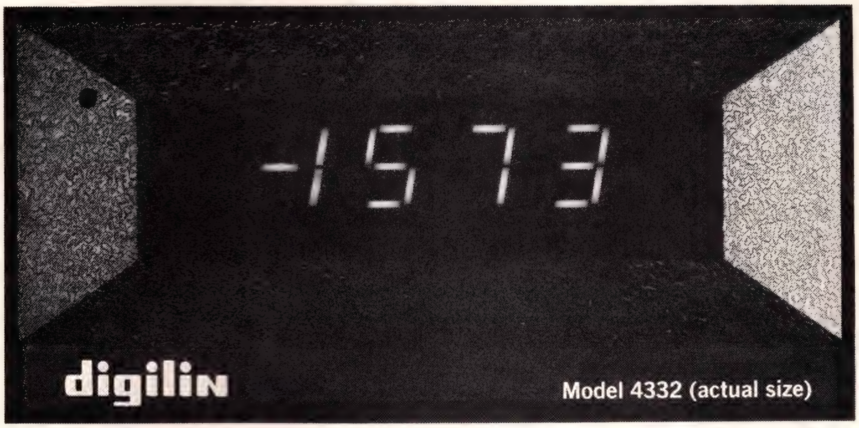

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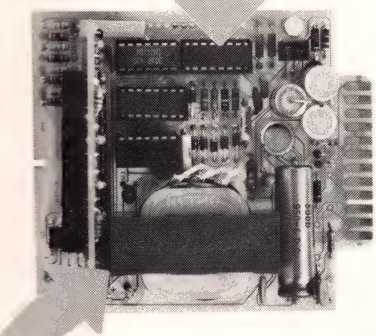

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# 1975

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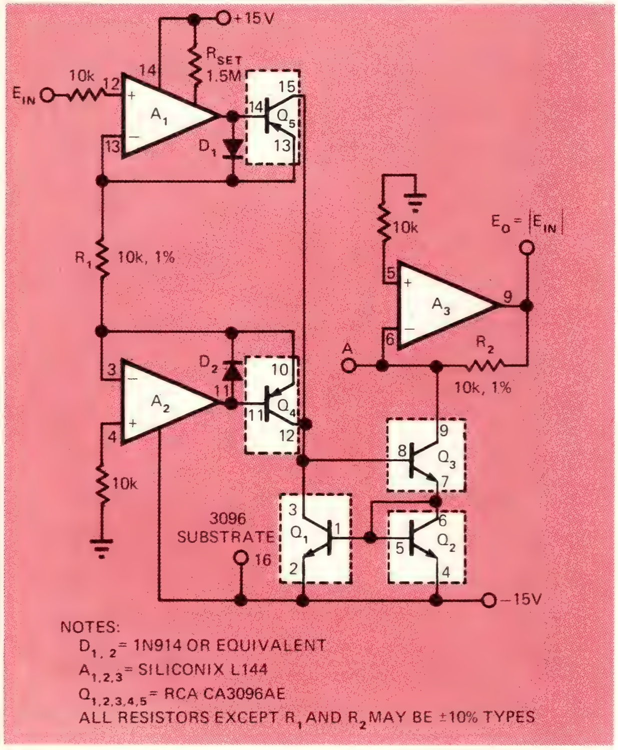
# EDN DESIGN AWARDS

## Full-wave rectifier needs only two precision resistors

**Steve Smith**
Quatt Wunkery, Richmond, CA

Accurate full-wave rectifiers (otherwise called absolute-value circuits) have many uses in analog signal conditioning systems. However, most common circuits use multiple expensive precision resistors. This novel circuit needs just two.

Op amps $A_1$ and $A_2$, plus pnp transistors $Q_4$ and $Q_5$, form an operational rectifier with a current-mode output. When $E_{IN}$ is positive, the output current path is through $A_1$, $D_1$, $R_1$ and $Q_4$. When $E_{IN}$ is negative, path is through $A_2$, $D_2$, $R_1$ and $Q_5$. In either case, the output current is unipolar, being equal to $R_1E_{IN}$.



**For critical applications**, op-amp set current can be reduced to minimize offset errors. Remaining error can be nulled by injecting current into current-summing node (Point A).

$Q_1$, $Q_2$ and $Q_3$ form a unity-gain current mirror to reflect the current from the pnp collectors (which float at ± $E_{IN}$) back to a current-summing node.

$A_3$ is a current-to-voltage converter using $R_2$ as the scale factor. Since $R_1$ and $R_2$ alone set the scale factor, only these two need be precision resistors. All the other resistors can be ±10% types.

Input voltage range is set by the common-mode range of the op amps and the breakdown ratings of the components. The circuit shown easily accommodates a ± 10V signal.

If a high-impedance output ($E_0 = -|E_{IN}|$) is desired, delete $A_3$, substitute a resistor ($\leq R_1$) from $Q_3$'s collector to ground, and use any dual op amp.

The circuit shown had a 5-mV output offset error, due mainly to op-amp currents. For critical applications, one can reduce the set current (by raising $R_{SET}$) to minimize the error. However, this will reduce output current capability. You also can increase $R_2$ to 10.2k (instead of 10k) to compensate for the base current of $Q_4$ or $Q_5$. Remaining offset can be nulled in a reasonably stable manner by injecting a small current into the current-summing node (Point A). □

**To Vote For This Circuit**
**Circle No. 150**

### References

1. *Tektronix "Tekscope" Vol. 5, #6, Nov./Dec. 1973.*
2. *Jerald Graeme, "Full-Wave Rectifier Needs Only 3 Resistors," Electronics, August 8, 1974, p. 104.*

## Binary-to-BCD converter implements simple algorithm

**Jim Barnes** and **Jerry Tonn**
Motorola Semiconductor Products Div., Phoenix, AZ

To provide visual read-outs, it is frequently necessary to convert from a 4-bit binary number (within the machine) to a 5-bit external word that is the BCD number value from 0 to 15. Various format methods of performing this conversion appear in current literature, but they are usually applicable to large numbers of bits and tend to be rather complicated. However, in this case, since we have only four binary bits it is practical to use a quad, 2-channel data selector with an exclusive-NOR function. With it we can implement a simple algorithm which applies to the numbers 0 through 15.

| BINARY | | | | BCD | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| D | C | B | A | E′ | D′ | C′ | B′ | A′ | n | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | A′ = A<br>B′ = B<br>C′ = C<br>D′ = D<br>E′ = 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 3 | |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 5 | |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 6 | |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 7 | |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 8 | |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 9 | |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 10 | $A' = A$<br>$B' = \overline{B}$<br>$C' = BC$<br>$D' = 0$<br>$E' = 1$ |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 11 | |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 12 | |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 13 | |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 14 | |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 15 | |

**Fig. 1—Just a piece of wire** implements the first equation in each set. Variable "A" does not appear in remaining equations.

From the conversion table (**Fig. 1**), one can see that if the binary number is 0 through 9, the use of the binary number with the half digit being 0 is indicated. If the binary number is 10 through 15 and the half digit is one, you must begin counting from zero. In the equations shown, the primed numbers are BCD, "A" corresponding to the LSB and "E" corresponding to the half digit. By inspection, one can see that the first equation in each set can be instrumented by just a piece of wire. Note also that "A" does not appear in the remaining eight equations. Thus, we can eliminate it from further consideration. This allows us to implement the configuration of **Fig. 2,** where the first three binary columns are the binary input (omitting the LSB) and the last four columns are the desired BCD bits (again omitting LSB "A").

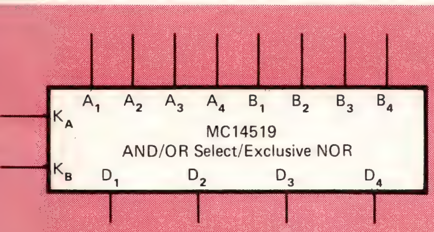
**Fig. 3** shows the block diagram and truth table of the MC14519 device. It also includes the equation for the exclusive-NOR function. Looking at **Fig. 4,** it is apparent that if the binary "D" signal is used for $K_B$, and the function B+C is used for $K_A$, the proper BCD codes will be generated for n′ = 1, 2 and 3 (**Fig. 2**), when inputs $A_0 = B$, $A_1 = C$ and $A_2 = A_3 =$ ZERO.

| | BINARY | | | BCD | | | | |
|---|---|---|---|---|---|---|---|---|
| n′ | D | C | B | E′ | D′ | C′ | B′ | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | $B' = B$<br>$C' = C$<br>$D' = 0$<br>$E' = 0$ |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | |
| 2 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | |
| 3 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | |
| 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | $D' = 1$ $B' = C' = E' = 0$ |
| 5 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | $B' = \overline{B}$<br>$C' = B \cdot C$<br>$D' = 0$<br>$E' = 1$ |
| 6 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | |
| 7 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | |

**Fig. 2—Omitting the LSB,** ("A"), produces this reduced truth table.

For the states n′ = 5, 6 and 7, control inputs $K_A$ and $K_B$ both equal ONE, producing the exclusive-NOR function. Desired output $B' = \overline{B}$ is generated by connecting input $B_0$ to ground $(B\odot 0 = \overline{B})$. By connecting the B signal to input $B_1$, we have the conversion $C' = C\odot B = C\cdot B + \overline{C}\overline{B}$. The first half of the equation $(C' = C\cdot B)$ is the desired output. The second half $(C' = \overline{C}\cdot\overline{B})$ are generated with the exclusive NOR by connecting $B_2$ to $V_{DD}$ and $B_3$ to ground, as shown.

Two remaining cases to evaluate are n′ = 0 and 4. Evaluating n′ = 0 is trivial, since where $K_A = K_B =$ ZERO, the device is in the inhibit mode, thus forcing all outputs to the desired LOW states. Evaluating n′ =



TRUTH TABLE

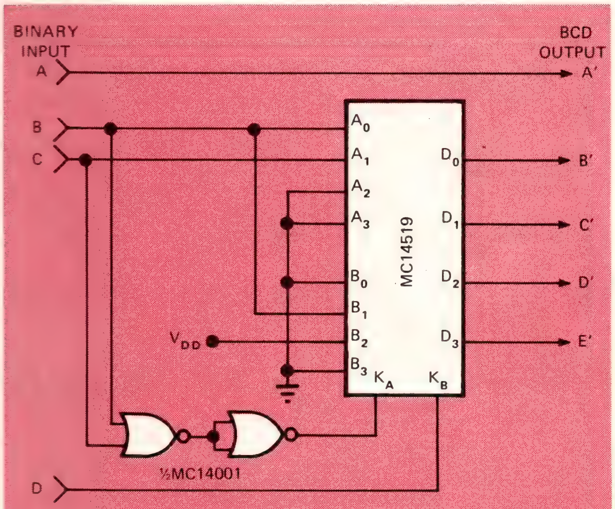
| CONTROL INPUTS | | OUTPUT | FUNCTION |
|---|---|---|---|
| $K_A$ | $K_B$ | $D_n$ | |
| 0 | 0 | 0 | INHIBIT |
| 0 | 1 | $B_n$ | TRANSFER B |
| 1 | 0 | $A_n$ | TRANSFER A |
| 1 | 1 | $A_n \odot B_n$ | EXCLUSIVE NOR |

NOTE:

$A_n \odot B_n$ MEANS $A_n$ (EXCLUSIVE NOR) $B_n$;

i.e., $A_n \odot B_n = A_n \cdot B_n + \overline{A}_n \cdot \overline{B}_n$

**Fig. 3—Equation for exclusive-NOR function** is included with this block diagram and truth table of the MC14519 Quad 2-channel data selector.



| | CONTROL | | MC14519 OUTPUTS | | | | BCD OUTPUTS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| n′ | $K_A$ | $K_B$ | $D_0$ | $D_1$ | $D_2$ | $D_3$ | B′ | C′ | D′ | E′ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | $A_0$ | $A_1$ | $A_2$ | $A_3$ | 1 | 0 | 0 | 0 |
| 2 | 1 | 0 | " | " | " | " | 0 | 1 | 0 | 0 |
| 3 | 1 | 0 | " | " | " | " | 1 | 1 | 0 | 0 |
| 4 | 0 | 1 | $B_0$ | $B_1$ | $B_2$ | $B_3$ | 0 | 0 | 1 | 0 |
| 5 | 1 | 1 | $B_0 \odot A_0$ | $B_1 \odot B_1$ | $B_2 \odot B_2$ | $B_3 \odot B_3$ | 0 | 0 | 0 | 1 |
| 6 | 1 | 1 | " | " | " | " | 1 | 0 | 0 | 1 |
| 7 | 1 | 1 | " | " | " | " | 0 | 1 | 0 | 1 |

**Fig. 4—Just one-and-a-half packages** are needed for the complete binary-to-BCD converter.

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4, B = C = ZERO; therefore $K_A$ = ZERO results in transferring the $B_N$ inputs to the device outputs. Checking the circuit in **Fig. 4,** we see that providing inputs $B_0 = B_3 =$ ZERO, $B_2 =$ ONE and $B_1 = B =$ ZERO will produce the desired outputs for the case $n' = 4$. Comparing the truth tables of **Figs.** 2 and **4,** we see the desired binary-to-BCD conversion is uniquely accomplished. ☐

**To Vote For This Circuit**
**Circle No. 151**

# Digital sample/hold simplifies communications timing

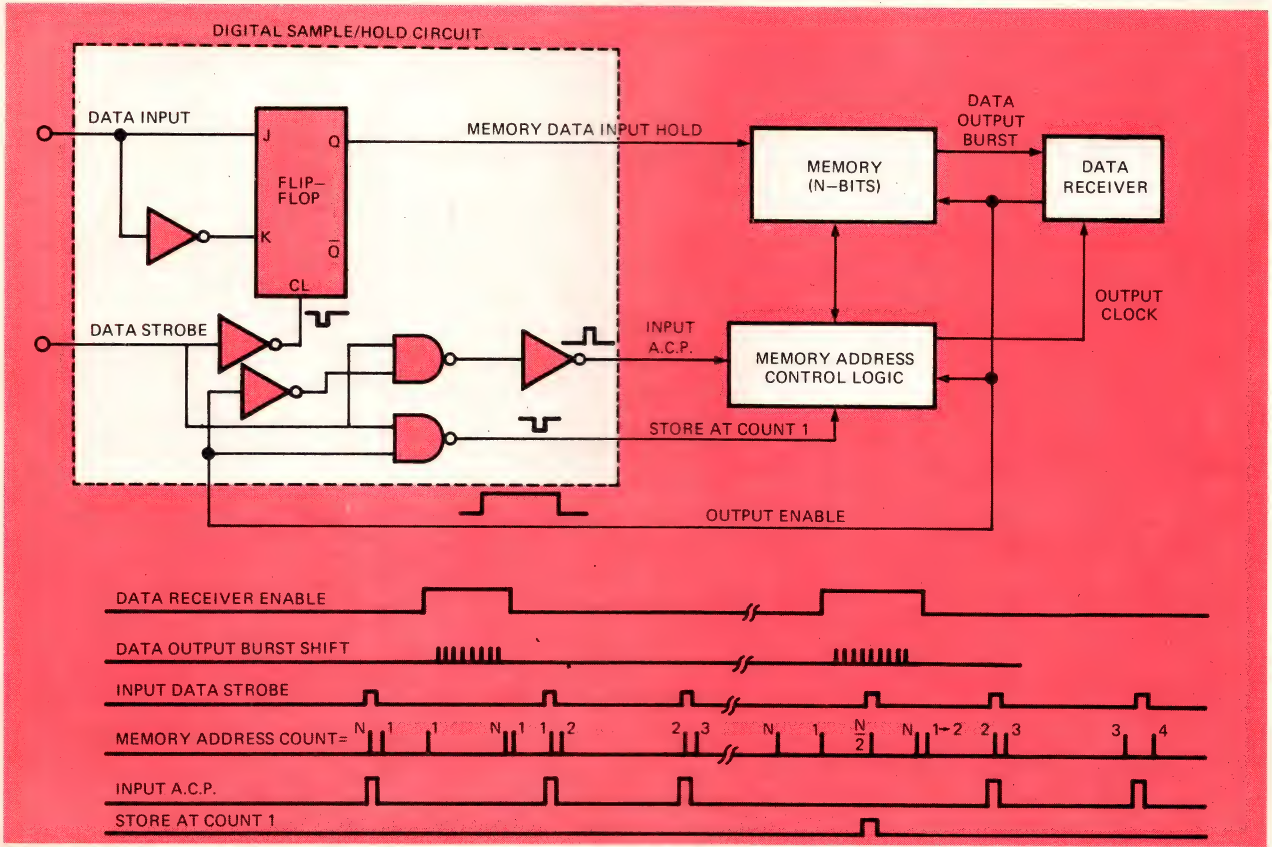
**Alphonso H. Marsh**
Digital Equipment Corp., Maynard, MA

Often it's necessary to establish digital data communications between two asynchronous, independent devices by using a memory buffer. The buffer must be of sufficient word length to allow accumulation of data from the low-frequency input. Simultaneously, it must have the capability to output accumulated data to the independent, asynchronous output receiver at a suitable high-frequency burst.

Obviously, if the memory is in the process of serially outputting an accumulated word, it cannot read-in data from the asynchronous input without addition of an input location tracking scheme and output address sequencing counter. However, by using a sample/hold circuit, the memory address sequencing counter can control both input and output operations. If an input should occur during the output transmission operation, the digital sample/hold will simply store the input data bit until the memory address sequencing counter is ready for it.

In the system shown, during output transmission the input advance counter pulse (A.C.P.) is inhibited. A data bit is read into the memory when this bit is HIGH; the counter is advanced after the trailing edge. Input data is clocked into the sample/hold flip-flop on the rising edge of the data strobe pulse. "Signal Store at Count 1" causes the memory address control logic to strobe its input data in location 1 at the end of the output burst cycle. It also advances the location counter to Count 2. ☐

**To Vote For This Circuit**
**Circle No. 152**



**When an input occurs during output transmission,** digital sample/hold stores input bit until the memory address sequencing counter is ready to accept it.

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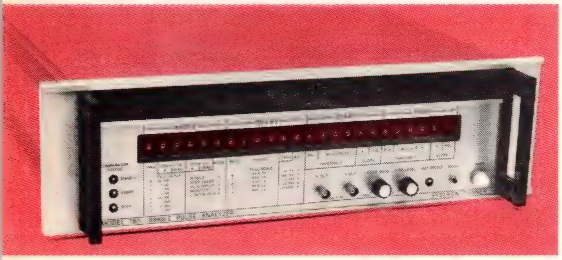

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Unlike waveform analyzers, the pulse analyzer can measure single-shot or nonrepetitive pulses. This unique ability removes the usual need for 1000 pulses/measurement, and permits rapid measurement of low repetition-rate signals. Checking of a memory, for example, can be done at 3000 bits/sec.

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**Circle No. 140**

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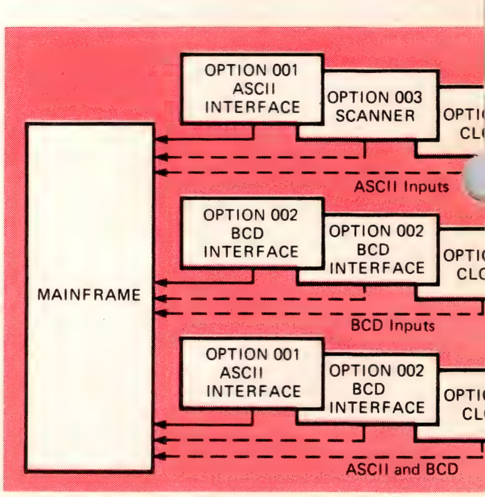
*PROGRESS IN INSTRUMENTATION*

Flexibility, reliability and quiet operation are the key features of this printer (**Fig. 1**). Modular construction allows an almost custom design for each job.

**Fig. 1—Six LED's** are used for Hewlett Packard's Model 5150A thermal printer front panel clock display. All clock-related functions are controlled from the front panel.

Quiet operation is achieved by the use of a thermal printing head. The design, proved out in other Hewlett-Packard instruments, is available in either 10 or 20 column widths. Using a 5×7 dot matrix, it prints the characters at a rate of more than three lines/second.

When connected to an HP communications bus, the thermal printer operates in any of three capacities: as a "listen-only" device; as an addressable listener; and, as a controller, sequentially addressing and sampling a number of data sources. The bus also provides systems capability with digital multimeters, frequency counters, power meters, network analyzers and a capacitance bridge.



The 5150A mainframe costs $800. Price of the ASCII option is

$175; the BCD option, $110 (two required for 20 columns). The scanner adds another $175, and the clock costs $250. Units are on the shelf now.

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**Circle No. 141**

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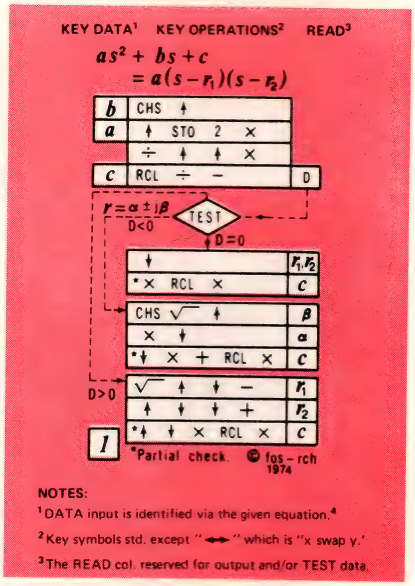

*Partial check. © fos-rch 1974

NOTES:

[1] DATA input is identified via the given equation.[4]

[2] Key symbols std. except "⟷" which is "x swap y."

[3] The READ col. reserved for output and/or TEST data.

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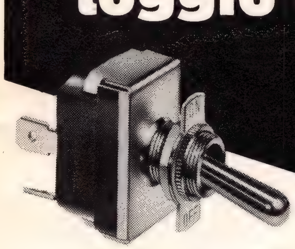

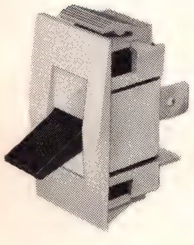

Proven, reliable McGill detent-action mechanisms. Broad selection of capacities (from 6 to 20 amp.), terminals and circuit arrangements to meet your needs. Metal or plastic bats in many shapes and colors. Snap-in types to facilitate style requirements. Request Catalog 89. McGill Mfg. Co., Inc., Electrical Div., Valparaiso, Ind. 46383.

**McGILL® ENGINEERED SWITCHES**

*Available from recognized McGill Master Switch Distributors.*

*For more information, Circle No. 36*

**Philips PM5771, a pulse generator with < 2.4 nsec risetime designed for TTL/ECL work**

Rugged enough and simple enough for industrial use. Pushbutton controls simplify selection of operating modes. Fast, easy calibration minimizes down time. Can be stacked for true dual channel operation. Priced at $ 1695.00

- Rise and fall times adjustable to <2.4 nsec. Permits ECL tests at rated conditions.
- Internal triggering to 100 MHz; external to 50 MHz.
- Amplitude from 80 mV to 10V in 50 Ohms; baseline offset to ± 5V.
- Single, double pulses. Gated continuous, or single shot.
- Output positive or negative, normal or inverted
- Jitter less than 50 psec.
- Pulse width and delay from 5 nsec to 100 msec.
- Duty cycle nearly 100% with inverted output.

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More functions/ranges • field proven • large displays • rugged metal cases • high acceptance • low prices • short delivery

Model 7004A All-function unit measures dc/ac volts, dc/ac current and resistance with excellent overload protection. AC response to 100 KHz. ±0.01% DC accuracy. Optional internal battery pack and carrying case. Basic price $715.

Model 7205 26 ranges. Resolves ±1 microvolt DC, 1 milliohm resistance, ±1 nanoamp current. Measures dc/ac volts, dc/ac current and resistance with excellent overload protection. ±0.005% accuracy. Display digits over ½" tall. Lead-compensated ohms. Optional isolated BCD output. Basic price $1205.

For immediate details, call our Quick Reaction line (415) 682-6471 collect, or contact Systron-Donner at 1 Systron Drive, Concord, CA 94518.

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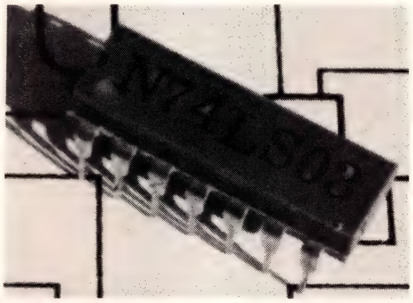
*For more information, Circle No. 37*

## SEMICONDUCTORS

**N-CHANNEL STATIC SHIFT REGISTER IS FULLY COMPATIBLE.** These shift registers are fully TTL/DTL compatible and require no external pull-up. IM7733, a static 1024-bit shift register, uses n-channel gate MOS enhancement mode technology and requires one +5V supply. Organized in a 1024×1 matrix, the devices are pin-for-pin compatible with the Signetics 2533 and TI3133. IM7733CPA (plastic) costs $9.90(100-999), 0 to 75°C. IM7733CDA (ceramic) is $16.80(100-999), −55 to +125°C. Intersil Inc., 10900 N. Tantau Ave., Cupertino, CA 95014. Phone(408)257-5450.

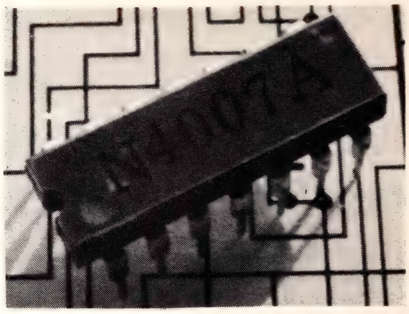
**Circle No. 150**



**LOW-POWER SCHOTTKY USES OPEN-COLLECTOR OUTPUTS.** Circuit expansion is featured on 6 TTL NAND gates and 2 hex inverters with open-collector outputs. Typ. propagation time is 16 nsec when driving a 15 pF load. Power dissipation is 2 mW/gate at 50% duty cycle. Available in both commercial and MIL temp. ranges, the devices are offered in plastic and ceramic. N74LS01A, quad 2-input positive NAND, 0 to 70°C, 50¢(100). S54LS22F, dual 4-input positive NAND gates, −55 to 125°C, $2.20(100). Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **Circle No. 151**

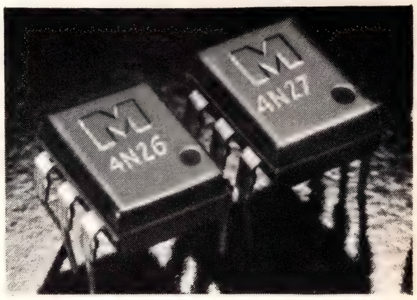
**8k N-CHANNEL ROM'S ACCESS IN 500 NSEC.** NCM6570, a mask programmable 8k-bit power select character generator, contains 128 characters in a 7×9 matrix. The NCM6571 is a preprogrammed version of the 6570 with a modified USASCII code. NCM6572, also a preprogrammed version of 6570, does not shift characters that normally extend below the baseline. Mounted in a 24-pin DIP, all are fully TTL compatible. $18(100). Nitron, 10420 Bubb Rd., Cupertino, CA 95014. Phone(408)255-7550.

**Circle No. 152**



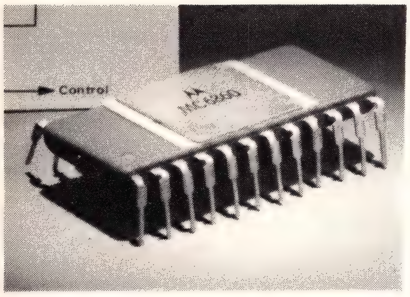
**CMOS CIRCUIT INCLUDES LINEAR AND DIGITAL FUNCTIONS.** Two complementary pairs of FET's and 2 inverter transistors are contained in the N4007A. Aimed at pulse shapers, linear amplifiers and threshold detectors, the device features flexible input power requirements from 3 to 15V. Power dissipation is 10 nW, while input current is < 10 pA. Temperature range is −40 to 85°C. 14-pin DIP, 47¢(1000). Signetics, 411 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)-739-7700. **Circle No. 153**

**SCHOTTKY MSI REGISTER OFFERS HIGH SPEED.** The AM25S09, a quad 2-input register, functionally replaces the 74S157 and 74S175. The device performs the same functions with typ. power dissipation of 37.5 mW—a 32% reduction. Tested to MIL-STD-883, the unit is available in a 16-pin package. Prices vary from $18.87 to $4(100), according to temp. and package. Advanced Micro Devices Inc., 901 Thompson Pl., Sunnyvale, CA 94086. Phone(408)732-2400. **Circle No. 154**



**OPTO ISOLATORS ARE JEDEC REGISTERED.** Using an infrared LED device coupled to a silicon planar phototransistor, the series is similar to MCT2. The 4N25 and 4N26 have typ. current transfer ratio of 50%; the 4N27 and 4N28, 30%. Isolation varies from 2.5 to 0.5 kV. Collector-to-emitter breakdown voltage is 30V min. (typ. 65V) and bandwidth is 300 kHz. 4N25, $2.95(1-99); 4N28, 94¢(1000). Monsanto Co., Electronics Div., 3400 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-3300.

**Circle No. 155**

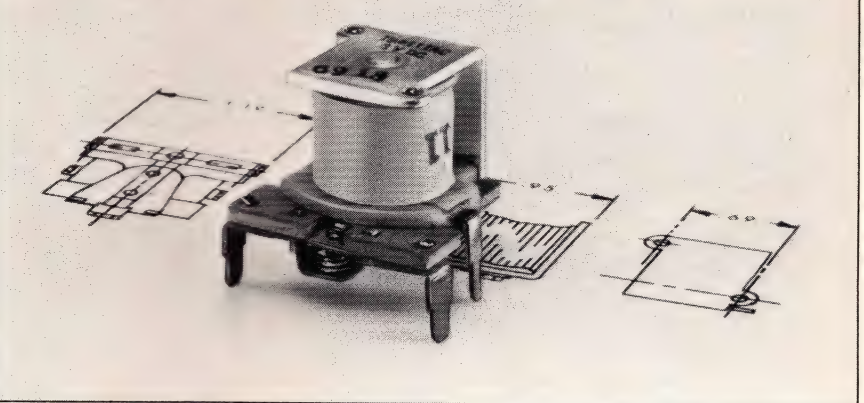


**SINGLE-CHIP MODEM EMPLOYS FSK.** This N-MOS device, a 0-600 bps digital modem, provides modulation, demodulation and supervisory control functions necessary to implement a serial data-communications link. The MC686OL operates from a single supply and is TTL compatible. Modes of operation include full duplex, half duplex and answer only and answer/originate. Temperature range is from 0 to 70°C. $75(1-24). Motorola Inc., Semiconductor Products Div., Box 20924, Phoenix, AZ 85036. Phone(602)244-3466. **Circle No. 156**

**IC MULTIPLIER/DIVIDERS HAVE GUARANTEED ACCURACIES.** Laser trimmed and completely self contained, this new series of monolithic IC's provides 1 and 2% accuracies. Available with differential inputs, the units feature 25V/μsec slew rate and 1 MHz bandwidth. Overload recovery time is 3 μsec and rated output is ±10V@±5 mA. Output impedance is 1Ω while noise is kept at 3 mV rms (10 kHz to 10 MHz). Prices range from $26 to $48(1-24) depending upon temp. and accuracy. Burr-Brown, International Airport Industrial Park, Tucson, AZ 85706. Phone(602)294-1431. **Circle No. 157**

**ANALOG FUNCTION ARRAY SIMPLIFIES INSTRUMENTATION.** Two precision comparators, 2 analog samplers and 2 current sources comprise this 16-pin DIP IC. The ER201M can serve as a logarithmic converter for a digital display, or can be used in a variety of instrumentation applications such as precision dual timer/oscillators. Temperature range is from −55 to 125°C. $15(100). Electronics Research Group, 22 Mill St., Arlington, MA 02174. Phone-(617)646-9760. **Circle No. 158**

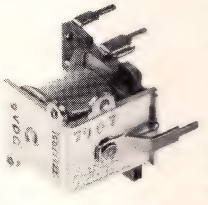
# 10 amps of switching in a 1″ cube!



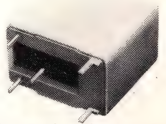
## We call it our Series 19 Relay. You'll call it one of the most compact and reliable packages you've ever used.

Remarkable 10 amp Series 19 relay is low in cost, too — less than $1.00 each in quantity. But price is only part of the story. The Series 19 also offers the advantages of miniaturization and the capacity to handle heavy switching loads. Result: more performance in a smaller overall package. Contact arrangement is SPDT. Rated 10 amps at 28 vdc or 115 v, 60 hz. Coil voltages available range from 3 to 24 vdc. The Series 19 is an ideal choice for a multitude of low level to 10 amp switching applications, including remote control, alarm systems and many other industrial and commercial uses.

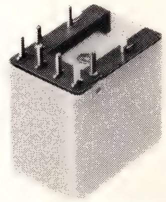
Equally important, the Series 19 is part of a whole family of interrelated low-cost relays which will lend themselves to multiple usage in the same system. Included are:



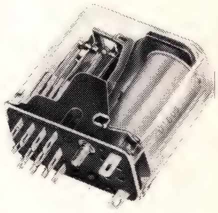
**Series 10.** Sensitive, low cost, highly reliable SPDT relay rated at 3 amps, 28 vdc. Coil voltages 3-24 vdc. Can be used for a wide range of industrial and commercial control functions and alarm systems.



**Series 28.** Same as Series 10, but furnished with a dust cover for use in appliance controls, remote TV tuning, industrial process controls and similar functions.



**Series 38.** DPDT, 3 amp 28 vdc contacts. Coil ratings 3-24 vdc. Applications include business machine controls, antenna rotor controls, industrial process controls, etc.



**GP.** A miniature general purpose relay with 2, 4, or 6 PDT contacts, rated 1, 2 or 5 amps, 28 vdc or 115 v, 60 hz. Coil voltages: 6-115 vdc. Consider the GP for copiers, business machines, control or alarm systems, etc. Available with single or bifurcated contacts.

**Send for information. Complete technical data on NAPCC relays available on request. Write today.**

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***For more information, Circle No. 38***

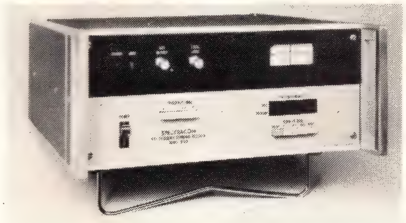
**DESK-MODEL PRINTING CALCULATOR FEATURES MEMORY SYSTEM.** The TI-620's memory allows summation of products, quotients or totals into the memory register. Numbers may be subtotaled and totaled, as well. The calculator also multiplies and divides by a constant and figures percentages, add-on and discount calculations. It has full 12-digit capacity. Size of the TI-620 is 10-1/4×13-3/4×4-3/4 in. $299.95. Texas Instruments Inc., Box 5012, M/S 84, Dallas, TX 75222. Phone(214)238-3741.
**Circle No. 159**

**LOW-COST PACKAGE JOINS THE TM 500 GROUP.** The 3 plug-ins are the FG 503 function generator that produces "clean" sine, square and triangle waveforms over a broad frequency range; the DM 502 digital multimeter that offers an up-to-date mix of ranges, including dB; and the DC 504 digital counter/timer that features an 80-MHz 5-digit display, and gives RPM, totalizes, and measures periods with high resolution. Prices are $325, $295 and $350. Tektronix, Inc., Box 500, Beaverton, OR 97005. Phone(503)644-0161.
**Circle No. 160**

**5-MHz FUNCTION GEN. PROVIDES SWEEP, AM, FM AND AM/FM.** Model 129's carrier generator produces sine, square, triangle, pos pulse, neg pulse and pos sine waveforms from 0.1 Hz to 5 MHz. An internal AM/FM generator produces square, triangle and sine waveforms from 1 Hz to 1 MHz for modulating the carrier generator. The carrier may be manually, externally or internally gated or triggered. $795. Dana Exact Electronics, Inc., Box 160, Hillsboro, OR 97123. Phone(503)648-6661.
**Circle No. 161**

**LED RETRO-REFLECTIVE PHOTO RELAY USES MODULATED LIGHT.** In the Models 35RRC and 35RRCT, a beam splitter separates the incoming and outgoing pulsed light beams that are emitted by the LED and returned via a reflector. The pulsed light, when amplified, operates a 10A plug-in relay. The devices operate effectively in any ambient light and to 170°F, require no maintenance and draw only 2W. <$100. Automation Products Mfg., Inc., 2600 N.W. 1st Ave., Boca Raton, FL 33432. Phone(305)391-1881. **Circle No. 162**

**50-MHz UNIVERSAL COUNTER FEATURES AUTORANGING.** Model 6250A performs frequency, multiple period, time interval, ratio and totalizing measurements. It provides autoranging that selects a max. display resolution, both preset and manual trigger-level selection, leading-zero suppression, 25-mV rms input sensitivity, an 8-digit display and BCD output of all measurements. Each input channel has selectable attenuator and slope controls. $740. Systron-Donner Corp., 10 Systron Dr., Concord, CA 94518. Phone(415)676-5000.
**Circle No. 163**



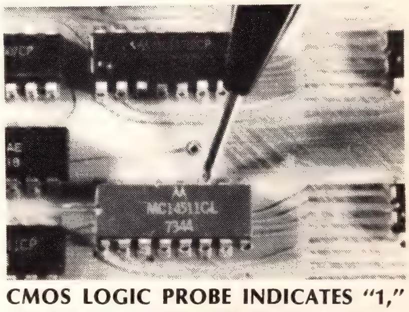
**WWVB RECEIVER'S OUTPUT IS PHASE LOCKED TO NBS.** A frequency-difference counter and phase comparator enable calibration of frequency standards, frequency synthesizers, counters and oscillators to NBS accuracy. The Model 8160's frequency-difference counter has 0.01-Hz resolution and digital readout. There are phase-locked outputs at 0.1, 1, 5 and 10 MHz. $1300. Delivery 90 days ARO. Spectracom Corp., 87 Wedgewood Dr., Penfield, NY 14526. Phone(716)381-4827.
**Circle No. 164**

**X-Y RECORDER FITS SCHOOL AND SMALL-LAB NEEDS.** Model 7015A is an 8-1/2×11-in. X-Y recorder with 3 ranges—0.01, 0.1 and 1V/in.; mechanical pen lift, universal pen holder, continuous-duty dc servo system and electrostatic paper holddown. Slewing speed is 20-in./sec. $945. Delivery 90 days ARO. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501.
**Circle No. 165**

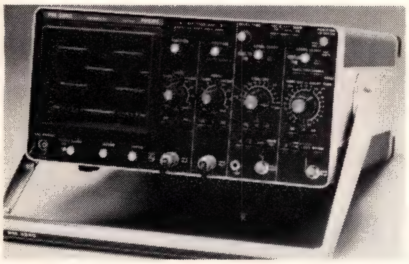
**READ PEAK VALUES OF ANALOG EVENTS WITHOUT A SCOPE!** A peak-read option for use with the V/E-13 DVM and V/E-20A digital strain indicator provides a method of accurately measuring both recurrent and nonrecurrent events. When a dynamic analog signal is fed in, an instantaneous comparison is made to a previously stored value. When the stored value is exceeded, a new updated value is immediately displayed. Vishay Instruments, 63 Lincoln Hwy., Malvern, PA 19355. Phone(215)647-5115.
**Circle No. 166**

**WAVEFORM GENERATOR EMPLOYS OPTICAL SCANNING.** Model CS-1 produces an electrical signal that faithfully reproduces a waveform drawn or photographed on a small glass slide. The slide is inserted into a slot in the front panel, and the pattern is electronically scanned, amplified, and made available at the output of the generator. Frequency range is from 40 to 250,000 Hz; however, pulse times may be made as short as desired. $1725. Electro-Physical Research, Inc., Box 817, Sandy Hook, CT 06482. Phone(203)426-0148.
**Circle No. 167**

**LOW-COST LINEAR IC TESTER MEASURES 7 PARAMETERS.** It measures plus and minus bias currents, offset current, offset voltage, bandwidth, open-loop gain and common-mode voltage. Optional features include programmable power supplies and a built-in oven for measuring temperature drift of the above parameters. Plug-in circuit boards allow simple and rapid testing of most existing IC's, including the new dual and quad op amps. $885. Delstad Electronics, 861 Revere Ave., Bronx, NY 10465. Phone(516)586-0238. **Circle No. 168**



**CMOS LOGIC PROBE INDICATES "1," "0" OR PULSE CONDITIONS.** The probe will operate on all complimentary MOS logic voltages (3-18V dc) and has its LED's located near the probe tip. Voltages of <45% $V_{DD}$ give a logic "0" indication, while those >55% of $V_{DD}$ give a "1." The pulse indicator flashes for 0.2 sec each time a pulse of 500 nsec or greater is present. A 2 MΩ input impedance keeps circuit loading to a minimum. $25. Questronics, Inc., Box 15803, Salt Lake City, UT 84115. Phone(801)262-9923.
**Circle No. 169**



**PORTABLE 50-MHz DUAL-TRACE SCOPE WEIGHS ONLY 18.5 LBS.** In the PM3240, remote dc switching for all functions makes possible an optimum control-panel layout. Key features are an 8×10 cm screen, 5 mV/div. sensitivity at full bandwidth and 10 nsec/div. max. sweep rate. The 50-MHz bandwidth and 7-nsec risetime can be displayed in separate, alternate, chopped and X-Y modes. Power drain is only 23W. $1470. Probes, $90 extra. Philips Test & Measuring Instruments, Inc., 400 Crossways Park Dr., Woodbury, NY 11797. Phone(516)921-8880. **Circle No. 170**

**STEPPING MOTOR INDEXING SYSTEM GIVES 5000 STEPS/SEC.** The high-speed system 260 stepping-motor indexing system features compact design (6×7.5×7.5 in.), complete control logic (slew-jog, forward-reverse, local-remote), an adjustable internal clock, 200 and 400 step/revolution control, automatic ramping, a self-contained power supply and a 5-digit incremental indexer. It needs no dropping resistors and is 90% efficient. $1110. Aerotech, Inc., 101 Zeta Dr., Pittsburgh, PA 15238. Phone(412)963-7470. **Circle No. 171**

**LINE-POWERED 4-1/2-DIGIT DPM USES OPTO-ISOLATED INPUT.** With its Beckman display and ratiometric capability, the AD2008 measures bipolar voltages over a F.S. range of ±1.9999V. Accuracy is 0.005% of reading ±50 μV ±1 digit. The gain TC is 15 ppm/°C, and automatic zero circuitry corrects for zero offsets. MOS-LSI logic permits power consumption of only 4W. $295. Analog Devices, Inc., Box 280, Norwood, MA 02062. Phone(617)329-4700. **Circle No. 172**

**SLIDE-RULE CALCULATOR HANDLES COMPLEX MATH FUNCTIONS.** The keyboard on the SR-16 has 10 digit keys, a decimal key, 16 function keys and 3 memory keys. Slide-rule functions include reciprocals, squares, square roots, raising a displayed number to a power, logarithms, raising base 10 to a power, raising base e to a power and natural logs. Numbers are displayed (on a 12-digit LED readout) in full-floating decimal point or scientific notation. $99.95. Texas Instruments, Inc., 13500 N. Central Expressway, Dallas, TX 75222. Phone(214)238-2011. **Circle No. 173**

**PRODUCTION TEST STATION HANDLES DIGITAL LOGIC BOARDS.** Model 1010 is a high-speed tester with the capability of one-pass, GO/NO-GO testing, and is program compatible with the larger Trendar 2000A production test station. It incorporates 128 digital signal sources that generate input patterns for the board being tested. Signals are generated at selectable rates up to 4,000,000 patterns/sec. $7500. Fluke-Trendar Corp., 500 Clyde Ave., Mt. View, CA 94040. Phone(415)965-0350. **Circle No. 174**

**UNIVERSAL CASSETTE SYSTEM REPLACES PAPER TAPE.** Model 330 is a plug-compatible replacement for all paper-tape readers and punches. It provides increased reliability, greater operating convenience through front panel control, and greater speed (up to 33× faster synchronously and 8333× faster asynchronously). Also its packaging density is higher. Many versions such as single or dual transport, FIFO buffered at 128 or 256 characters, and ANSI/ECMA formatter are available. Dicom Industries, 715 N. Pastoria Ave., Sunnyvale, CA 94086. Phone(408)732-1060. **Circle No. 175**

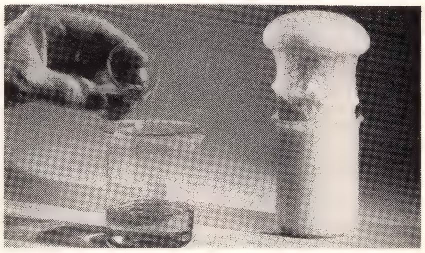
**POCKET-SIZED DIGITAL THERMOMETER READS 0.1° INCREMENTS.** The Heat-Prober instantly reads the temperature of surfaces, liquids, powders or gases. There are 15 interchangeable probes covering −50 to 500°C or −50 to 900°F. Accuracy is ±0.5%±1 digit. It operates from a built-in rechargeable battery, or can be line operated. Temperature changes are updated 3×/sec. William Wahl Corp., 12908 Panama St., Los Angeles, CA 90066. Phone(213)391-7234. **Circle No. 176**

CRYSTAL CLEAR
EPOXY CASTING RESIN

Several transparent Stycast® resins are offered for making display embedments or castings. A convenient chart is available to aid in selection of the most appropriate system. It is yours for the asking.

FOR MORE INFORMATION CIRCLE #9

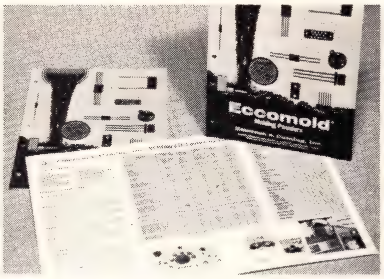
LOW-DENSITY
FOAM-IN-PLACE
ENCAPSULANT



ECCOFOAM® FP and FPH are liquid foam-in-place urethane systems to provide shock protection and give mechanical support to air-borne and space-borne electronic components. Densities 2 to 26 lb/cu-ft; no outgassing. These encapsulants are spec'd in everywhere and have been used in most U.S. satellites and space vehicles.

FOR MORE INFORMATION CIRCLE #10

ECCOMOLD®
EPOXY MOLDING
COMPOUNDS



Comparative physical, electrical and processing properties of Eccomold transfer molding compounds are in colorful chart. Typical applications are indicated.

FOR MORE INFORMATION CIRCLE #11

Emerson & Cuming, Inc.
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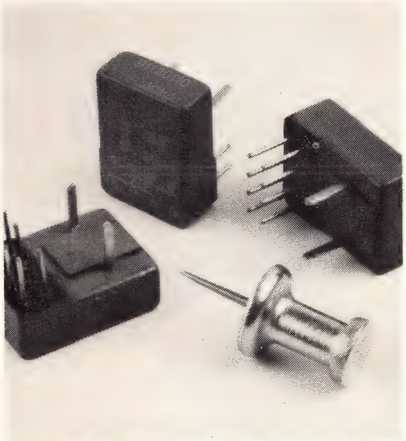
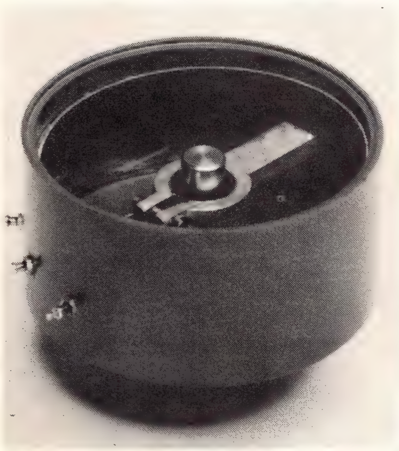


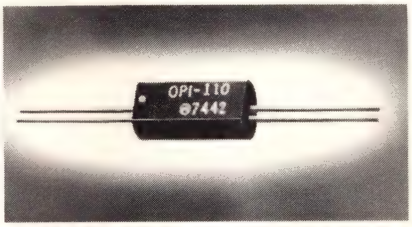
**FLAT PACK ROTARY-ARMATURE DPDT RELAYS CONSERVE SPACE.** The hermetically-sealed Model 911 relays measure only 1/4 in. high. Available in 6, 12, 26.5, 48 and 76V dc versions, they meet MIL-R-5757D requirements. Contacts are rated to 1A, 26.5V dc resistive, with life expectancy of 100,000 operations at max. load. $7-$8. Availability 8 to 10 wks. WABCO Aerospace Dept., Swissvale P.O., Pittsburgh, PA 15218. Phone(412)242-5000. **Circle No. 177**

**SOLVENT SAFELY BREAKS THE HOLD OF SUPER GLUES.** Stock No. 42,255 allows re-alignment of critical gluing work and easily removes excess glue from completed projects. It also will get fingers un-stuck and dissolve super-glue bonds from skin, clothing, tools and instruments. A 1-oz bottle costs $4.25 postpaid. Edmund Scientific Co., 380 Edscorp Bldg., Barrington, NJ 08007. Phone(609)547-3488. **Circle No. 178**



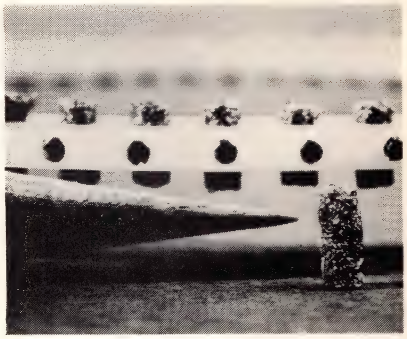
**PRECISION POTS BENEFIT FROM A DUAL RESISTIVE ELEMENT.** These hybrid pots combine the advantages of both wirewound and conductive plastic elements. They are produced by coating the wiper path or the entire element of a wirewound with conductive plastic. Wear characteristics resemble those of conductive-plastic pots but performance is similar to that of W.W.'s. Current production is limited to custom designs. New England Instrument Co., 14 Kendall Lane, Natick, MA 01760. Phone(617)873-9711. **Circle No. 179**

**SILICON TRANSIENT SUPPRESSOR LINE SPANS 6V TO 200V RANGE.** Models for either symmetrical or unidirectional circuit protection are available. They dissipate 500W (1 msec) in DO-35 packages or 1500W (1 msec) in DO-41 packages. Breakdown voltage tolerance is ±10%, and the dynamic impedance is 1.5 to 175Ω depending on breakdown voltage. Unidirectional, $3.55; bi-directional, $6.65 (100-999). Microsemiconductor Corp., 2830 S.Fairview St., Santa Ana, CA 92704. Phone(714)979-8220. **Circle No. 180**



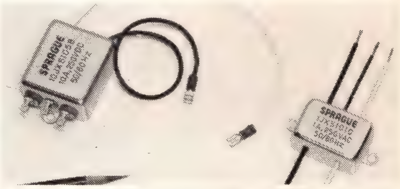
**COMPACT OPTO ISOLATOR FITS HIGH-DENSITY REQUIREMENTS.** The OPI 110 consists of an npn silicon planar phototransistor coupled with a high-efficiency GaAs IR emitter mounted in a 0.3-in.D×0.5-in.L plastic package. It features 10 kV isolation, typical current-transfer ratio of 40% with 10 mA input current, and typical switching time of 4 μsec. $2.90(1000). Optron, Inc., 1201 Tappan Circle, Carrolton, TX 75006. Phone(214)242-6571. **Circle No. 181**

**ORANGE LED DISPLAYS JOIN GREEN, RED AND YELLOW.** The MAN3600 series of 0.3-in. orange digits has the same mechanical configuration as comparable units in the MAN50 series (green), MAN70 series (red), and MAN80 series (yellow). Also, OEM prices will be the same at the 1000-qty. level. Intensity is typically 1200 mcd at 10 mA/segment. MAN3600 is housed in 0.4-in. wide packages with leads on 100-mil centers. $2.20 (1000). Monsanto Commercial Products Co., 3400 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-3300. **Circle No. 182**

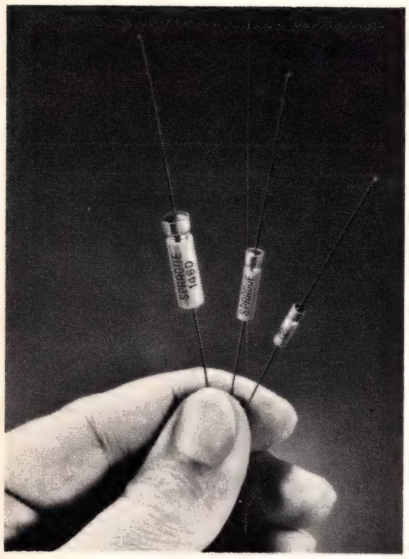


**"FUZZ BUTTON" CONTACTS SOLVE CONNECTION PROBLEMS.** FUZZ BUTTONS are resilient, low-impedance, multipath contact elements produced by die compressing a charge of cohesive, fine knitted wire mesh to a desired shape and density. They provide low resistance, redundancy of contact and mechanical compliance. Standard materials include gold-plated copper silver, gold-plated beryllium silver, Monel and silver-plated brass. Technical Wire Products Inc., 129 Dermody St., Cranford, NJ 07016. Phone(201)272-5500. **Circle No. 183**

**ECL PACKAGING BOARDS ACCOMODATE SIP RESISTOR NETWORKS.** Designated ECL21, 25 and 26, the boards correspond to the ECL1, 5 and 6 series (except for the resistor module provision). The SIP modules contain 7 resistors, with 1 lead common for connection to a −2V bus. Resistors are generally 120Ω, 1/8W. From $1.83 to $3.39/pattern. Augat Inc., 33 Perry Ave., Attleboro, MA 02703. Phone(617)222-2202. **Circle No. 184**



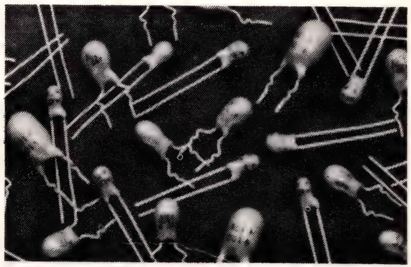
**LINE FILTERS PROTECT BOTH WAYS, COST LITTLE.** Series JX5100 general-purpose power line filters protect equipment from line noise as well as the line from equipment noise. They control line-to-ground interference and filter both sides of the line. U.L. recognized for operation at 125 or 250V ac, they are available in a wide variety of current ratings (1 to 30A) and terminal configurations. Line-to-ground capacitance is only 0.01 μF, and max. leakage current is 0.5 mA. Sprague Electric Co., Marshall St., North Adams, MA 01247. Phone (413)664-4411. **Circle No. 185**



**SINTERED-ANODE TANTALUMS RESIST FLOW-SOLDERING DAMAGE.** With their reliable TFE-fluorocarbon elastomer seal, Type 146D Tantalex$^R$ capacitors offer outstanding resistance to temperature cycling and permit trouble-free flow-soldering. They are available in 3 case sizes, in voltage ratings of 6 through 60V dc at a temperature of +85°C, and with capacitance ratings from 1 through 470 μF. Capacitance tolerances of ±20% or ±10% are standard. Sprague Electric Co., North Adams, MA 01247. Phone(413)664-4411. **Circle No. 186**

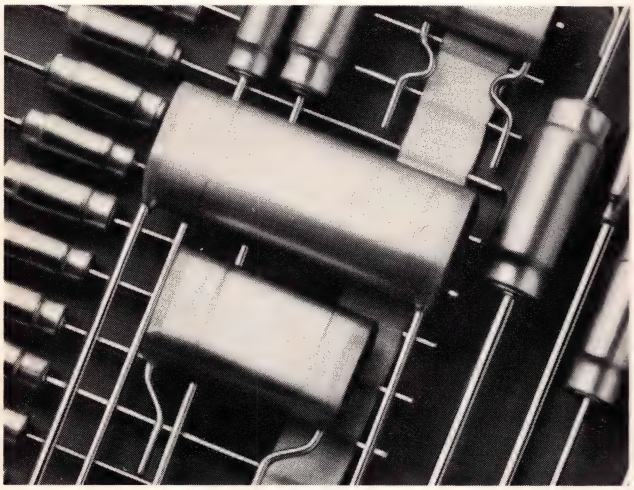
**TRANSIENT VOLTAGE PROTECTORS GUARD 5V LOGIC.** Two JEDEC-registered TransZorb$^R$ transient voltage suppressors are offered: the IN5907, a glass to metal, hermetically-sealed device for military applications, and the molded IN5908 for commercial use. Both feature high energy-suppression capability—15 kW for 10 μsec or 1.5 kW for 1 msec. Their theoretical response time is $<1\times10^{12}$ sec. 90¢(10,000). General Semiconductor Industries, Inc., 2001 W. Tenth Pl., Tempe, AZ 85281. Phone(602)968-3101. **Circle No. 187**

**METAL-FILM RESISTORS MEET AND EXCEED MIL-R-10509 SPECS.** Type VM epoxy-coated resistors feature a high evaporation of metal alloy on ceramic substrate with gold end bands. Characteristics C, E and F are available in 1/8, 1/4, 1/2, 1 and 2W sizes. Tolerance ranges from 1 to 0.1%, while TC's of ±25, ±50 and ±100 ppm are offered. Vermont Precision Resistor Co., Box 1170, Stowe, VT 05672. Phone(802)253-8567. **Circle No. 188**



**DIPPED SOLID TANTALUMS DELIVER LONG SHELF LIFE.** Units of the T390 and T392 Series are offered with CV range of 0.1 to 680 μF, 3 to 50V dc. They may be specified in either 0.1 or 0.2-in. lead spacing to fit 0.1-in. pc-board grids. Standard tolerance is ±20% (±10% and ±5% available on special order). A typical 1 μF 35V, ±20% capacitor will cost from 10¢ in OEM quantities to 50¢ in quantities below 50 pieces. Union Carbide Corp., Box 5928, Greenville, SC 29606. Phone(803)963-6300.

**Circle No. 189**



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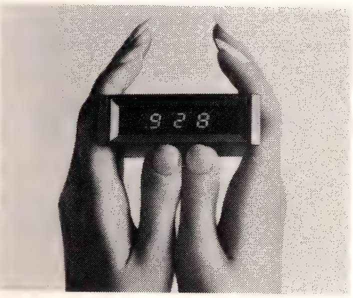

Full three digits.
Less than 1" high.
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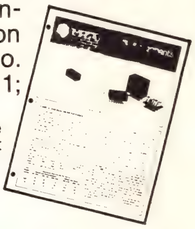
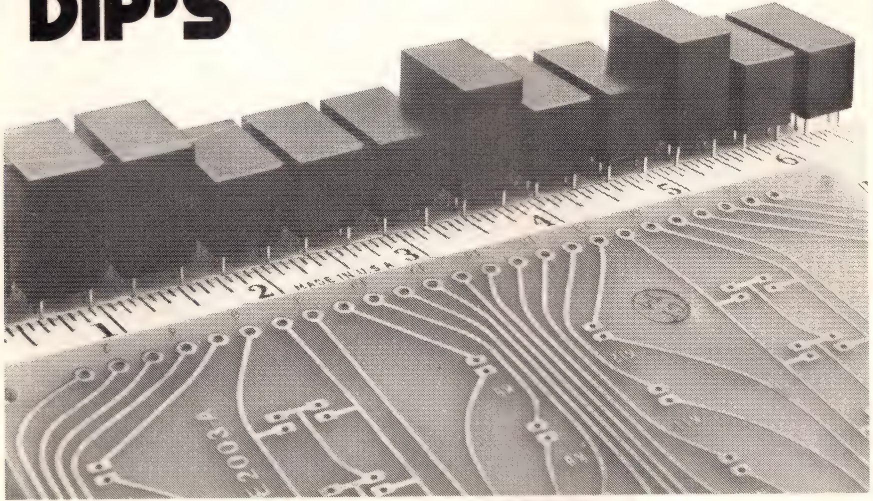
**...are now available in multiple-unit Dual In-Line Packages (DIP).** These unique 14 and 16-pin units will accommodate up to 8 capacitors, in various dielectric and capacitance combinations, for use in either automatic inserting or standard plug-in sockets. The packages save PC board space, inventory and handling time, and assembly costs. Get complete information today on these Skinny DIP's from Electrocube, 1710 So. Del Mar Ave., San Gabriel, CA 91776, (213) 283-0511; TWX 910-589-1609.



**FREE...**data file on request

**SKINNY DIP'S**



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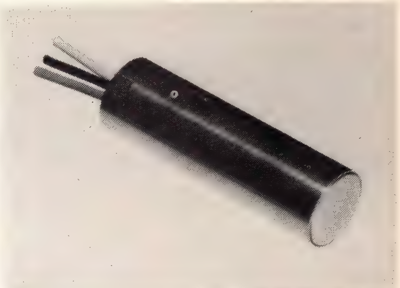
## COMPONENTS/MATERIALS

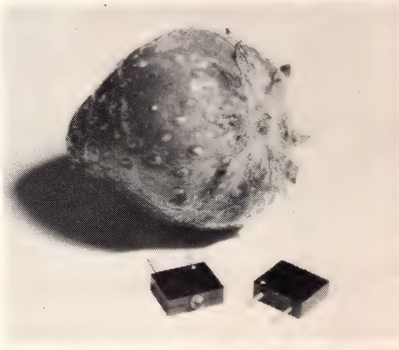


**PROXIMITY SWITCH SENSES ONLY NONFERROUS METALS.** Operating directly from 120V ac, Model 525 typically will sense aluminum at a distance of 1/4 in. and reliably switch up to 100W of power. No external power supply or amplifier is needed. The housing is steel. It measures 1×3-1/4 in. and accepts standard 1/2-in. conduit fittings. Switches are sensitive at the front face only. Both N.O. (Model 525-A) and N.C. (Model 525-B) outputs are offered from stock. TEPCO, 52500 Southdown Rd., Utica, MI 48087. Phone(313)731-4267.

**Circle No. 190**

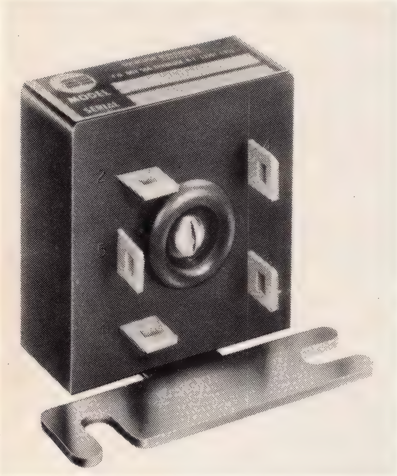
**COLD-CATHODE REGULATOR/REFERENCE DIODES OUTSHINE ZENERS.** ZD-series devices offer ±1V regulation, current range and TC superior to those of zeners, and operation at currents up to 10 mA without failure. Power surges of >50W can be handled. Available voltage and tolerance ratings are from 82 to 145V and 1 to 20%. The housing is a glass envelope 1.0625-in.L×0.244-in. max. dia. Signalite, 1933 Heck Ave., Neptune, NJ 07753. Phone(201)775-2490.

**Circle No. 191**



**NOW THE 555-SERIES LED COMES WITH PARALLEL OR 90° LEADS.** The 555-3xxx models have the pins coming out parallel to the LED so that when the unit is inserted onto a pc board the lamp faces directly upward. Pins in the 555-2xxx models emerge at 90° to the LED. Ten indicators fit side by side in 1 in. of space. Typical prices: 555-200x, 62¢ and 555-300x, 68¢. Dialight, 203 Harrison Pl., Brooklyn, NY 11237. Phone(212)497-7600.

**Circle No. 192**

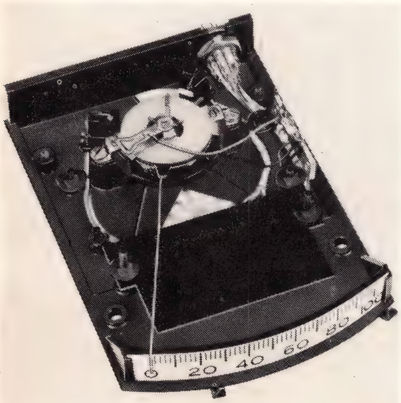


**FIXED OR VARIABLE DELAY INTERVAL TIMERS ARE ALL S.S.** Series SDS solid-state timers are available in fixed and remote adjustable delay ranges with lower limit of 0.1 sec and upper limit of 480 sec. Action is spst, delay on make. Available models accept inputs from 24 to 230V ac and 24 to 110V dc. Reset time is 50 msec during and after timing and the output rating is 1A ac and 100 mA dc. Syracuse Electronics Corp., Box 566, Syracuse, NY 13201. Phone(315)488-4911.

**Circle No. 193**

**MEASURE FORCE, OR PRESSURE, ON AN OHMMETER.** Microducers are small, low-cost force transducers that exhibit a resistance change with applied force. They feature long life, high repeatability and low hysteresis. Modules are available in force ranges from 0-1 lb. to 0-5000 lbs. Resistance change is typically 50k to 100 kΩ. I. T. Marketing, Box 6359, Anaheim, CA 92806. Phone(714)630-2601.

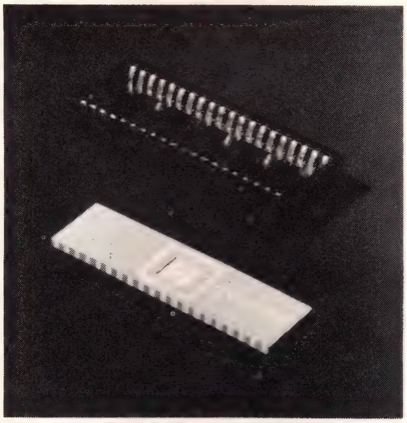
**Circle No. 194**



**EDGE-READING CONTROL METER IS ONLY 7/8-IN. THICK.** Completely redesigned, the ER-35 contactless meter is available with 1 or 2 set points and provides 4 control switching configurations. Both horizontal or vertical displays are available. The redesign is said to provide improved switching and a more reliable meter movement. Airpax Electronics, Box 8488, Ft. Lauderdale, FL 33310. Phone(305)587-1100.

**Circle No. 195**

**WROUGHT-GOLD TERMINAL INLAYS CUT LSI SOCKET COSTS.** Two 24-pin sockets, designated R724 and R724-2, use wrought-gold strips, metallurgically bonded to the copper-nickel alloy contacts. The smooth surface of the wrought inlays gives lower contact resistance than the porous surface of conventional gold plate. The R724 sockets are 0.28-in. H, while R724-2 is 0.15-in. H. $1.50 and 88¢ (100 to 500), respectively. Vector Electronic Co., 12460 Gladstone Ave., Sylmar, CA 91342. Phone(213)365-9661. **Circle No. 196**



**LEADLESS CERAMIC PACKAGE SNAPS INTO A CONNECTOR.** The edge-connector package fits most popular pin-connector devices and is similar to standard DIP ceramic packages except for the absence of leads. Its main advantage is the flexibility it provides in allowing replacement of the chip without tampering with the pc board. Sizes include 40, 28 and 24 leads. Plessey Inc., 8th and Harrison Sts., Frenchtown, NJ 08825. Phone(201)996-2121.

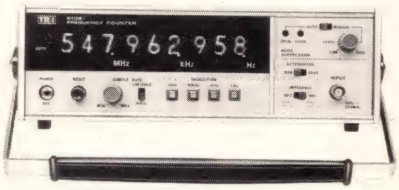
**Circle No. 197**

**FEP HEAT-SHRINKABLE TUBING WITHSTANDS 400°C.** FIT-400 FEP Teflon$^{R}$ tubing shrinks at a 2:1 ratio, (50%) at 200 to 350°F. It is available in 18 sizes from 0 to 24 AWG, and in packaged assortments of 6-in. lengths. Alpha Wire Corp., 711 Lidgerwood Ave., Elizabeth, NJ 07207. Phone(201)925-8000. **Circle No. 198**

# Kiss Noise Good-bye

The higher a counter's sensitivity and the wider the frequency measuring range, the more noise is superimposed on signals, right? Wrong. Not with high-input sensitivity/wide frequency range counters from T.R.I. You get noise-free measurement of even weak signals.

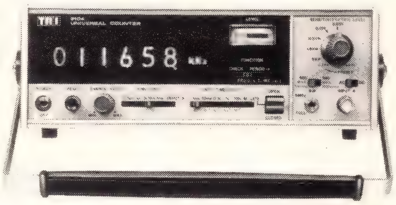
Model: 5108
Frequency Counter $950



**550 MHz measuring capability for $950**

Model 5108. Measures up to 550 MHz. 10 mVrms input sensitivity. Built-in automatic noise suppression. And a clear 9-digit display. Plus $5\times10^{-8}$/day stability. All for $950. How's that for economy? And how's this for flexibility, it's size-right for field use. Also a good choice for bench and systems applications.

Model: 5104
Universal Counter $519



**60 MHz measuring capability for $519**

Model 5104. A money-saver. Has a low-pass filter in the input to suppress noise. Measures up to 60 MHz. 50 mVrms input sensitivity. In addition to frequency, use it also to measure time intervals, frequency ratios, and to totalize. Weighs a carry-around 9.3 lbs. No other counter offers so much so economically.

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**T.R.I. Corporation**
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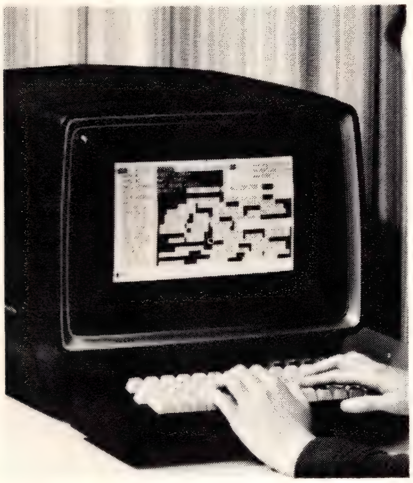
(408) 733-9080

***For more information, Circle No. 44***

# COMPUTER PRODUCTS



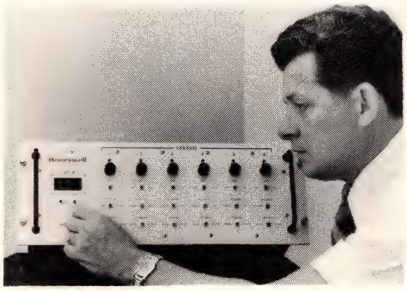
**MULTI-TALENTED INPUT AND DISPLAY SYSTEM DOES IT ALL.** The TD 820, built around a CRT, can be equipped with cassette tape stations, mini-discs, line printers and 3 different keyboards. Special display features include conventional white on black, black chars. on a white background, or a mixture of both. Additional capabilities permit blinking and "blank video." Optional magnetic-card reader prevents unauthorized use of the system. 960-char. is $6250, 1920-char. is $6800. Burroughs Corp., Detroit, MI 48232. Phone(313)972-7083.
**Circle No. 199**

**RUGGED μP WITHSTANDS HARSH ENVIRONMENT.** The ASC μP has been ruggedized to withstand vibration, shock, EMI/RFI, humidity and temperature extremes beyond the capabilities of commercial computers. The heart of the system is the Intel 8080 processor and associated components. Provision is made within the enclosure for optional I/O modules. The package is a standard ATR enclosure of 7-5/8×10-1/8×16 in. Applied Systems Corp., 24601 Harper, St. Clair Shores, MI 48081. Phone(313)779-8700. **Circle No. 200**

**UNINTERRUPTIBLE POWER SYSTEM SOLVES LINE PROBLEMS.** The DSU 710 is an on-line UPS designed to maintain conditioned ac power to critical computer systems. It is a complete self-contained system including battery charger, battery reservoir and output inverter regulator. Output from the DSU is an isolated 117V ac ±5% sine wave. Standard accessories include alarm indicators and automatic switching. $1425. Deltec Corp., 3849 Gaines St., San Diego, CA 92110. Phone(714)297-4466.
**Circle No. 201**

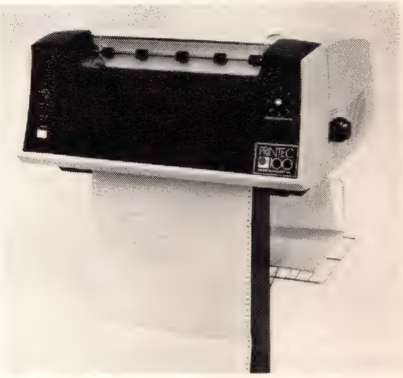
**REMOTE FRONT PANEL AVAILABLE FOR PDP-8/e.** Model RFP-80 is a small calculator-type keyboard with 7-segment LED octal display. It performs remotely all of the standard functions of the PDP-8/e programmer's console. Current memory address and selected register contents are displayed continuously. The package includes the bus plug-in interface circuit board, a thin 10 ft interconnecting cable and a plexiglass front panel replacement. $700. Douglas Electronics, Inc., 718 Marina Blvd., San Leandro, CA 94577. Phone(415)483-8770.
**Circle No. 202**

**STAND-ALONE PRINTER REQUIRES MIN. MAINTENANCE.** The compact, 5010 data terminal prints 34-char. lines at a rate of 110 char./sec. There are no moving parts when the unit is idle, thus reducing wear and insuring min. maintenance. The unit uses a 5×7 matrix to form the 64 ASCII alphanumeric and symbolic chars. in 2 colors on standard 3-3/4-in. adding-machine paper. Size is 12×18×6-1/2 in. Wt. 16 lbs. $1195. Victor Comptometer Corp., 3900 N. Rockwell St., Chicago, IL 60618. Phone(312)539-8200. **Circle No. 203**

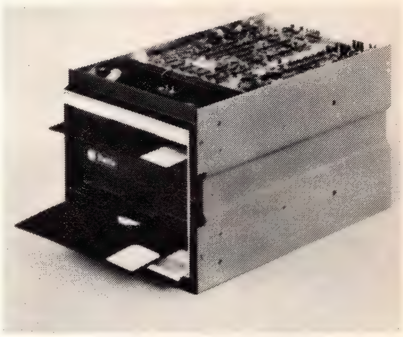


**TELETYPE MULTIPLEXER IS SAID TO REDUCE COSTS.** Six teletype signals can be multiplexed to 1 high-speed printer through this HC-650 multi-channel concentrator. Memory units store data until a full page has been accumulated. Each channel's data is then printed out in a switch-selectable sequence or by previously assigned priorities. The continuously adjustable inputs and outputs are 50 to 150 wpm and 100 to 2000 wpm, respectively. Honeywell Information Systems, 3602 W. Waters Ave., Tampa, FL 33614. Phone(813)932-5331.
**Circle No. 204**

**PROGRAMMABLE CONTROL SYSTEM IMPROVES RELIABILITY.** It includes a 256 word pROM memory, expandable to 2048 words; eight 115V ac input functions; and 8 output functions. The number of inputs and outputs is expandable to 256 functions in any combination. A separate programmer that uses simple relay ladder symbology, and a diagnostic card for easy machine and control troubleshooting are available options. $1189. Barber-Colman Co., 1309 Rock St., Rockford, IL 61101. Phone(815)877-0241. **Circle No. 205**



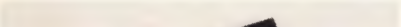
**PRINTER PACKAGE OPERATES WITH VARIAN DATA MACHINES.** Series 620 can be used with Varian operating system software without any modifications. The user receives a 100-cps printer, Varian interface card, diagnostics and a 15-ft cable. The printer can be supplied with either upper-case (only), or optional upper/lower-case character sets. Adjustable tractors allow paper width from 4 in. through 14-7/8 in. $4750. Printer Technology, Inc., Sixth Rd., Woburn Industrial Park, Woburn, MA 01801. Phone(617)935-4246.
**Circle No. 206**



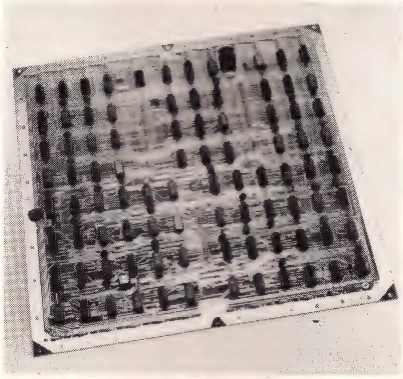
**DUAL FLEXIBLE DISC DRIVE FITS INTO SINGLE UNIT SPACE.** Series 10, Model 12 dual diskette drives offer copy capability, 6.2M bit capacity, IBM 3740 compatibility and ceramic/ferrite heads for longer diskette life. The unit can be mounted in a vertical, on-edge or flat position. $1100. Diablo Systems, Inc., 24500 Industrial Blvd., Hayward, CA 94545. Phone(415)783-3910. **Circle No. 207**

**μP AND TERMINAL COMBINE FOR INCREASED INTELLIGENCE.** Model OP-1 terminal contains 3 built-in μP's. The CPU is user programmable and allows operation with various host computers. The display μP performs fast roll/scroll and full screen-erase operations. Video reversal, blinking and half intensity are program controlled. The display is a window into memory. The I/O μP manages all data transfers on a cycle steal basis. $2285 (100). Delivery 90 days ARO. Ontel Corp., 3 Fairchild Ct., Plainview, NY 11803. Phone(516)822-7800. **Circle No. 208**

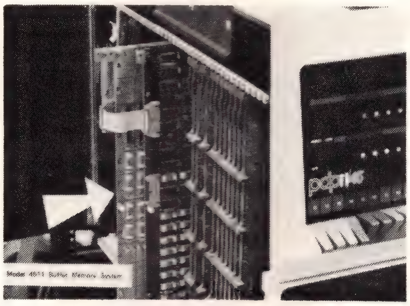
**DEBUG CONSOLE PERMITS FAST TROUBLESHOOTING.** The F801 is a hands-on program debugging tool for the PDP-11. It allows users to stop or interrupt the system at any point for examination of its various elements, and offers a unique backward look at the last 16 addresses that appeared on the UNIBUS$^R$. It occupies 5-1/4 in. of panel space and mounts in a standard DEC cabinet 19-in. rack. $1200. Formation, Inc., One Computer Dr., Cherry Hill, NJ 08003. Phone(609)424-1713.
**Circle No. 209**



**POWER SOURCE DRIVES 4k RAM'S FROM SINGLE 5V DC SUPPLY.** RAM-PAC$^T$ power sources supply +12V ±50 mV at 550 mA; −3V, −5V or −9V ±150 mV, at 10 mA; and an optional clock boost voltage of +15V at 25 mA. Load regulation is 175 mV at +12V and 100 mV on negative voltages. Output ripple is 150 mV p-p over 20 MHz BW. Units are short-circuit protected and operate over a range of 0 to 70°C. 2.8×2.8×0.4 in. $65. Reliability, Inc., 5325 Glenmont, Houston, TX 77036. Phone(713)666-3261.
**Circle No. 210**



**SINGLE CARD TAPE FORMATTER HANDLES UP TO 8 TAPE DRIVES.** Model 86008 accepts 8-bit parallel bytes, and converts them to the required phase-encoded serial format. Preamble, postamble and CRCC are generated internally during write operations and automatically removed during reading. The tape formatter provides all logic to read backwards and to justify the bits in a byte, plus it performs forward and reverse search for file marks. $570. Delivery is 3-4 wks. Qantex, 200 Terminal Dr., Plainview, NY 11803. Phone(516)681-8350. **Circle No. 211**



**MEMORY BUFFER INCREASES CPU EFFICIENCY.** Model 4511 provides a high-speed memory enhancement for the PDP 11/45. It will buffer the entire 124k words of main core memory at MOS speeds of 450 nsec—in lieu of the 32k words max. presently available from DEC. The plug-compatible design utilizes bipolar technology with 512 words by 16 bits of available storage. $11,810. Fabri-Tek Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. Phone(612)935-8811. **Circle No. 212**

For A Choice of Printed Circuit Mountable Connectors

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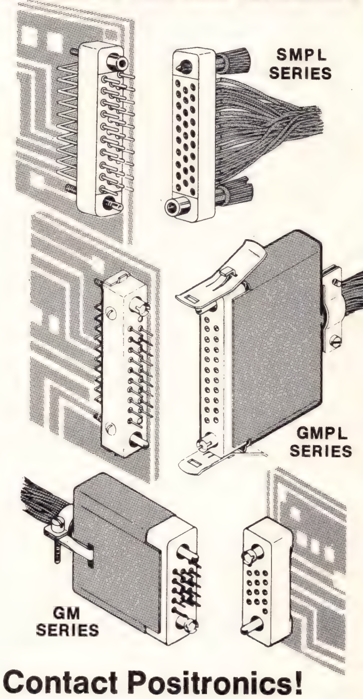

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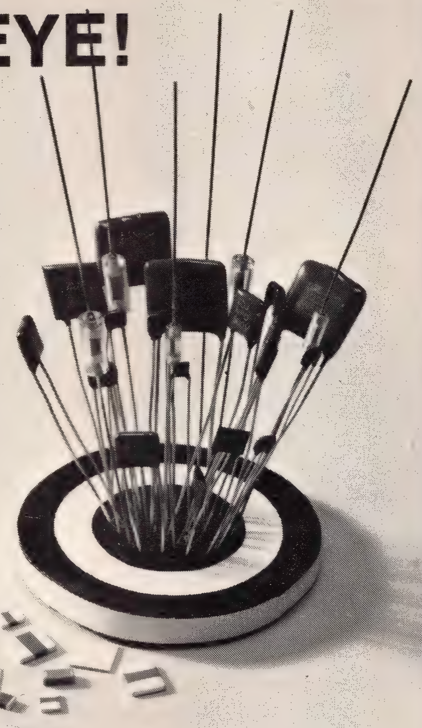

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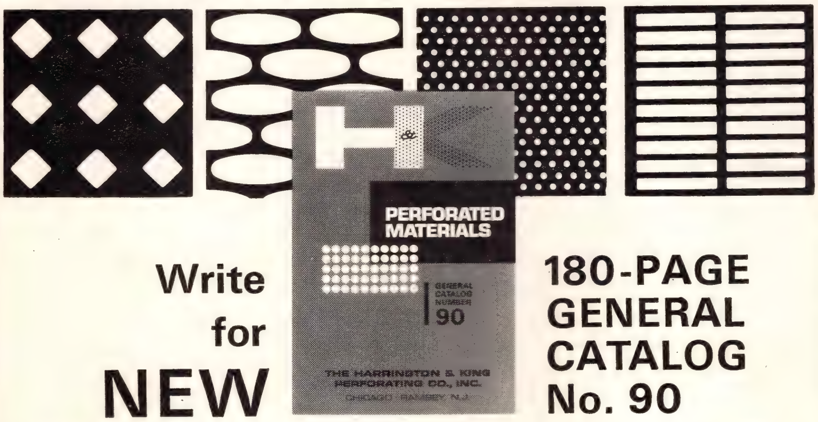
PERFORATED MATERIALS



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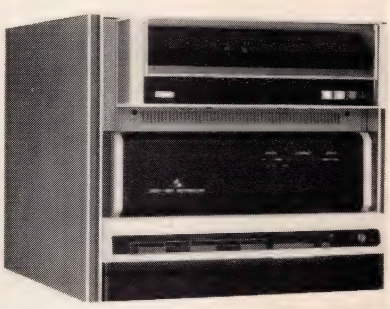
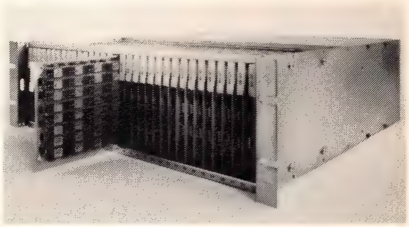
*For more information, Circle No. 50*

## COMPUTER PRODUCTS



**PDP-11 USERS NOW HAVE A SECOND-SOURCE DISC DRIVE.** All AED 2200 hardware, software and media are directly interchangeable with DEC's RK-11/RK-05, 03 system. The controller plugs directly onto the PDP-11 Unibus$^{R}$. It can carry out overlapped operations and has NPR and DMA features. Average random move is 70 msec, and the data transfer rate is 11.1 μsec/word. $5500(10). Advanced Electronics Design, Inc., 754 N. Pastoria St., Sunnyvale, CA 94086. Phone(408)733-3555. **Circle No. 213**

**DISC CONTROLLER FOR PDP-11 IS FULLY IBM COMPATIBLE.** The controller will interface up to 4 ORBIS Model 74 Diskette Drives to the PDP-11. It features overlap seek for faster throughput and IBM standard 26 sectors/track. Sector search, correction of track position and CRC generation and check are accomplished by hardware. Hardware generates all gaps, sync bytes, preambles, CRC bytes and postambles. Orbis Systems Inc., 3303 Harbor Blvd., Bldg. K4, Costa Mesa, CA 92626. Phone(714)556-8450. **Circle No. 214**



**4k RAM'S ALLOW HIGH-DENSITY, LOW-POWER MEMORY SYSTEMS.** The Monostore VII/modular memory system is designed around a 4096×1 N-MOS dynamic RAM with max. capacity of over 3.5M bits. Systems are TTL compatible and include timing, control, address register, input data register and refresh circuitry. Access time is 500 nsec; cycle time is 700 nsec. Nominal supply voltages are +12, +5 and −5V dc. Monolithic Systems Corp., 14 Inverness Dr. East, Englewood, CO 80110. Phone(303)770-7400. **Circle No. 215**

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*Edward G. Crosby and*
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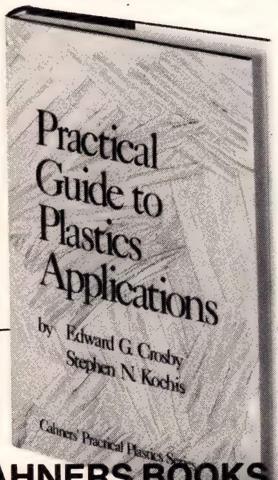
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**12-DIGIT BADGE READER READS ACCESS CODE AND EMPLOYEE ID.** Three access digits to open locks and 9 ID digits for print-out record are provided by the SCR-1012 badge reader. Mechanical sensors detect the badge's Hollerith code and actuate remote, full-wiping electrical contacts. Readout is of the static type providing parallel outputs for scanning at computer speed. Sealectro Corp., 225 Hoyt St., Mamaroneck, NY 10543. Phone(914)698-5600.
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**PORTABLE DIGITAL DATACASSETTE PROVIDES VERSATILITY.** Standard features of the 8410 include storage of 145,000 char./cassette; switch selectable speeds to 2400 baud; full remote control; automatic sensing for CR delay; fast forward mode; and a 120 ips rewind speed. This compact recorder is plug- and speed-compatible with many send/receive devices employing serial data interfaces. $760 in OEM quantities. Delivery 45 days ARO. Techtran Industries, Inc., 580 Jefferson Rd., Rochester, NY 14623. Phone(716)271-7953.
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**OEM MATRIX PRINTER CONSERVES SPACE AND MONEY.** The CDC 9316 printer handles 1-to-5 part, 4-to-16.75-in. forms. Front impacting the forms eliminates hammer framing (blocking) and adjacent char. ghosting. A full-line buffer memory permits loading up to 132-char. codes plus forms-advance code; and synchronous 173-char./sec printing of asynchronously received data. Each of the CDC 9316 character sets is contained on a single ROM. $2350. Delivery 90 days ARO. Control Data Corp., Box O, Minneapolis, MN 55440. Phone(612)853-4094. **Circle No. 218**

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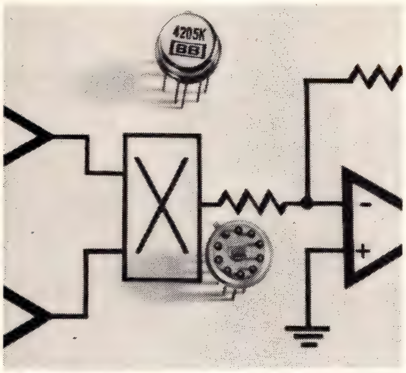
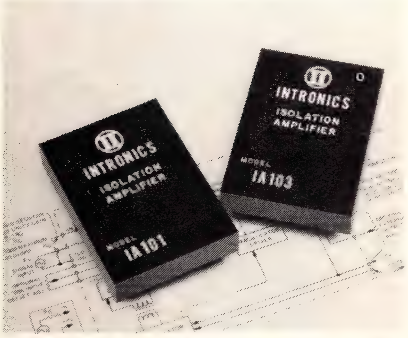
## CIRCUITS

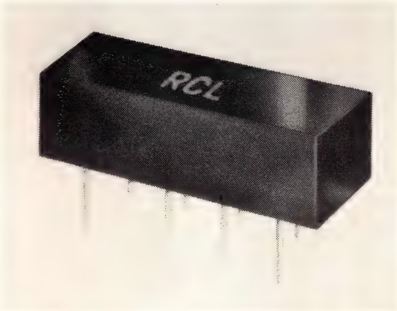


**MULTIPLIER/DIVIDERS GUARANTEE ACCURACIES WITHOUT TRIMMING.** Series 4205 differential-input monolithic devices guarantee accuracies of 1% (4205K, 4205S) and 2% (4205J) without external adjustment. Internal zener-regulated reference results in reduced sensitivity to supply voltage variations. All units have output rating of ±10V at 5 mA and output noise of 3 mV rms (10 Hz to 10 MHz). \$26(J), \$36(K) and \$48(S). Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. Phone(602)294-1431.
**Circle No. 219**

**SYNCHRO AMPLIFIERS HANDLE LOW-IMPEDANCE LOADS.** The C70 3185 101 is a Scott "T" buffer amplifier capable of driving Thevenen impedances as low as 11Ω. It accepts ac inputs proportional to the sine or cosine of an angle, and provides a 3-wire, 400-Hz, 11.8V line-to-line synchro stator output equivalent to the input angle. Over its operating temp. range of −55 to +105°C, output accuracy is within ±2 minutes. Singer Co., Kearfott Div., 1150 McBride Ave., Little Falls, NJ 07424. Phone(201)256-4000.
**Circle No. 220**



**MODULAR AMPLIFIERS PROVIDE HIGH ISOLATION AND ACCURACY.** The IA100 series includes the IA101 unity-gain buffer, IA102 low-drift adjustable gain model and the IA103/104 low input-current adjustable-gain models. All units feature accuracies of ±0.01%, and input/output isolation of 5000V. An additional feature of the series is a floating ±15V supply that can power transducers feeding the amplifier's input. Prices are \$125, \$155, \$165 and \$180 (IA101, 102, 103 and 104, respectively). Intronics, 57 Chapel St., Newton, MA 02158. Phone(617)332-7350.
**Circle No. 221**

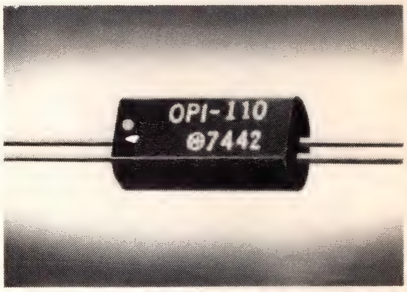


**DIGITAL DELAY MODULES REQUIRE NO EXTERNAL COMPONENTS.** A series of 3 unique models is offered in encapsulated packages, utilizing plug-in type pins for printed-board mounting. Delays of 50, 100 and 250 nsec are available. Delay increase from no-load to max.-load condition is approx. 2 nsec for each type unit. Designed to be compatible with TTL and DTL circuits, the units require no additional components to achieve specified delays. RCL Electronics, Inc., 700 S. 21st St., Irvington, NJ 07111. Phone(201)374-3311.
**Circle No. 222**

**DOPPLER RADAR MODULE SIMPLIFIES DETECTOR SYSTEMS.** The DX-489 module includes an integral antenna, Gunn-oscillator transmitter and a Schottky-barrier diode detector. The transmitter consumes <1W, and radiates approx. 8 mW of 10.525-GHz power. A low-gain antenna permits the packaging of a complete system capable of detecting a moving man at 100 ft. \$47.50. Amperex Electronic Corp., 230 Duffy Ave., Hicksville, NY 11802. Phone(516)931-6200. **Circle No. 223**

**SYSTEM MODULES COMBINE HIGH PERFORMANCE WITH LOW PRICE.** Deltaverta$^{R}$ products, based on delta-sigma modulation and time division, require only a single line to transmit all data, even for multichannel applications. Included are encoders, multiplexers, clocks, address generators, detectors, decoders and demultiplexers. Features include CMOS circuitry for low-power, multichannel operation (up to 64) and high accuracy (0.01%)—all at a typ. cost of <\$100/channel. Hybrid Systems Corp., 87 Second Ave., Burlington, MA 01803. Phone(617)272-1522.
**Circle No. 224**

**CRYSTAL OSCILLATOR FITS CRITICAL APPLICATIONS.** Model TK-9 is available in a frequency range of 4 to 15 MHz. Typical stability, with TTL output at 5 MHz, is ±0.5 ppm over the ambient temperature range of 0 to +60°C. Housed in a hermetically-sealed package 1.5 in. sq, the unit has a power requirement of +15V dc at -20 mA. Electronic Research Co., Box 913, Shawnee Mission, KS 66201. Phone(913)631-6700. **Circle No. 225**



**OPTO ISOLATORS FEATURE HIGH ISOLATION VOLTAGE.** The OPI 110 consists of an npn silicon planar photo-transistor coupled with a high-efficiency GaAs infrared emitter mounted in a plastic package. It features input to output isolation of 10 kV, and typical current transfer of 40% with an input current of 10 mA. Switching time of the unit is 4 μsec typ. \$2.90 (1000). Optron, Inc., 1201 Tappan Circle, Carrollton, TX 75006. Phone(214)242-6571. **Circle No. 226**

**TIMER IS INTENDED FOR EXTERNAL JUNCTION BOX MOUNTING.** The SCS series of solid-state timers has repeat accuracy of ±2% (typ.), a 50 msec max. reset time during and after time out, and a reliability rating of >100 million operations. Units come in any voltage values from 24 to 230V ac and 24 to 110V dc. Power consumption is 3W max. At 25°C, the load rating is 1A max., 40 mA min. for ac and 1A for dc. Operating temp. range is −10 to +60°C. \$9, with delivery 8 wks. ARO. Syracuse Electronics Corp., Box 566, Syracuse, NY 13201. Phone(315)488-4911. **Circle No. 227**

**FULL 4-MODE ENCODER GENERATES ITS OWN CLOCK SIGNAL.** The EA2000 is completely programmable, generating a 10-bit output word for each of the 99 keys and 4 modes. Use of a "ghost" key detection system allows keyboard interfacing without requiring diode isolation for each key. The unit is TTL compatible, and needs only +5V and −12V supplies. $15(100) in silicone package. Delivery is 6-8 wks. ARO. Electronic Arrays, Inc., 550 E. Middlefield Rd., Mt. View, CA 94043. Phone(415) 964-4321. **Circle No. 228**

**TONE-PAIR DECODERS SPAN WIDE FREQUENCY RANGE.** Each double frequency decoder will operate on any pair of preset frequencies from 20 Hz to 100 kHz. The prefiltered units work in the presence of other signals and can be supplied with a 1-sec time delay to minimize the effect of spurious signals. These decoders function with signal levels as low as 0 dBm, and require either a 12 or 24V dc supply. Reed-relay outputs are rated at 10W. $150. Douglas Randall, 6 Pawcatuck Ave., Pawcatuck, CT 02891. Phone(203)599-1750. **Circle No. 229**

**SOLID-STATE RELAY STANDS RUGGED INDUSTRIAL USAGE.** This digital-output device provides the link between the computer and industrial power circuitry. It accepts the computer's command output, discriminates it from spurious noise, and controls an integral solid-state relay. Control of currents up to 40A can be provided. It provides a selectable time delay, and can be locked in or out of the power circuitry by an independent enable signal. There is optical isolation of output from input. Towne Applied Technology, Inc., 228 Central Ave., Buffalo, NY 14206. Phone(716)891-4664. **Circle No. 230**

**ANALOG PHASE SHIFTERS SPAN WIDE RANGE OF FREQUENCIES.** The PS-A series of 5% frequency band-width devices is available with any center frequency from 1 to 18 GHz. Continuous voltage-tuned phase shift can be provided from a fraction of a degree to 360°. Typical of the line, the Model PS-A05 has a frequency of 10.2-10.5 GHz; phase shift of 0-25°; max. VSWR of 1.35 and max. insertion loss of 1.6 dB. Engelmann Microwave Co., Skyline Dr., Montville, NJ 07045. Phone(201)334-5700. **Circle No. 231**

**ADC DESIGNED FOR HIGH-SPEED DATA ACQUISITION SYSTEMS.** The 12-bit Model 4133 features a 2.5 μsec max. conversion time. Low-drift performance (±10 ppm/°C) ensures accurate linear operation over its 0 to 70°C temperature range. The unit has an internal 10V reference, with the capability for use as an external reference. Digital output is fully buffered to eliminate loading problems that would affect accuracy. $585. Teledyne Philbrick, Allied Dr., Dedham, MA 02026. Phone(617)329-1600. **Circle No. 232**

**SUPPLIES FURNISH HIGH POWER AT LOW COST.** Single- and dual-output models make up a line of 100W dc power supplies. Units feature a low ripple of 500 μV at full load, line and load regulation of 0.005% and 0.05% and full rating to 71°C ambient. Any output voltage between 3 and 30V can be furnished. There is no overshoot on either turnon or turnoff. $72 (single outputs), $85 (duals). Electrostatics, Inc., 7718 Clairemont Mesa Blvd., San Diego, CA 92111. Phone(714)279-1414. **Circle No. 233**

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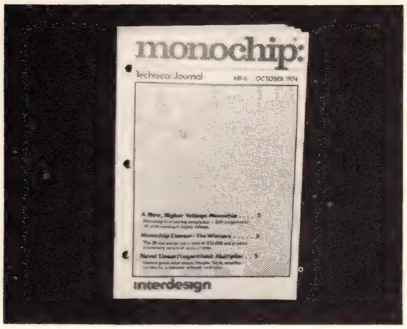
## LITERATURE



**MONOCHIP JOURNAL** features novel designs by the winners of Interdesign's Monochip Design Contest. A unique linear/log multiplier is highlighted. Interdesign Inc., 1255 Reamwood Ave., Sunnyvale, CA 94086. **Circle No. 234**

**STABILITY/CALIBRATION CHART** #1173 gives, in nomograph form, the data needed to determine how often a local standard must be recalibrated. It uses oscillator drift rate (stability) as the determining factor. True Time Instrument Co., 429 Olive St., Santa Rosa, CA 95401. **Circle No. 235**

**ELASTOMER SELECTION GUIDE** provides general descriptions and specific performance characteristics for 18 elastomers from natural rubber to chlorinated polyethylene. Included are chemical designations, ASTM-SAE designations, trade names and summaries of the major advantages and limitations of each. The guide also contains a quick reference chart of properties. The Stalwart Rubber Co., 160 Northfield Rd., Bedford, OH 44146. **Circle No. 236**

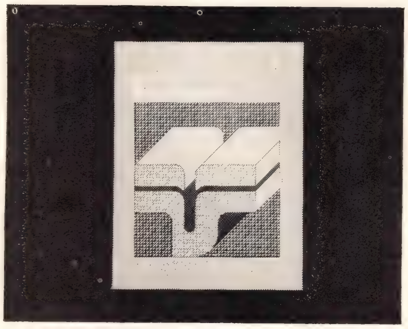
**OSCILLATORS.** An applications bulletin, entitled "How to Specify Crystal Oscillators," is complete with 16 illustrations and drawings. It covers clock oscillators, TCXO's and oven-controlled devices. A comparison of these types is included as well as a discussion on their use in timing applications. Vectron Laboratories, Inc., 121 Water St., Norwalk, CT 08854. **Circle No. 237**

**DIGITAL IC'S.** An application note describes the use of bipolar HiNIL (high noise immunity logic) and 74C CMOS IC's in systems that require both high noise immunity and high drive capability. Specific design examples illustrate the benefits of this system combination. Teledyne Semiconductor, 1300 Terra Bella Ave., Mt. View, CA 94040. **Circle No. 238**

**VOLTAGE STANDARD.** Two brochures describe the Model AN3100 secondary dc voltage standard. A technical brochure gives a product description, the instrument's features, the theory of operation and complete specs. The 6-pg. applications handbook covers 31 typical uses for the standard. Analogic Corp., Audubon Rd., Wakefield, MA 01880. **Circle No. 239**

**"SMART" DATA LOGGER.** This 52-pg. brochure fully describes the Digitrend 220 "SMART" Data Acquisition System, a second generation multipoint recorder. Options, specifications and all prices, as well as photographs, are presented. Doric Scientific Corp., 3883 Ruffin Rd., San Diego, CA 92123. **Circle No. 240**

**CHIP CAPACITORS.** Data sheet P22 characterizes a series of porcelain chip capacitors designed exclusively for microwave applications. Test results, and equipment used to measure impedance, insertion loss and rf heating, are detailed along with a discussion of quality and dissipation factors. Vitramon, Inc., Box 544, Bridgeport, CT 06601. **Circle No. 241**



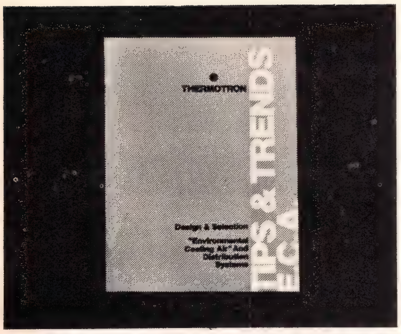
**"VERSAPLOT™ SOFTWARE."** A 12-pg. brochure describes the Universal and Integrated Versaplot software packages. It covers the power, adaptability and simplicity of the 2 packages. Subroutines are discussed in detail. Four pgs. of typical plot samples indicate the range of application, print quality and toning capability. Versatec, 10100 Bubb Rd., Cupertino, CA 95014. **Circle No. 242**

**SWITCHING.** A 36-pg. manual, illustrated with technical drawings and graphs, details the physical principles of switching, and discusses the capabilities and performance of reed switches, reed relays, axial travel switches, reed switch pushbuttons and mercury switches. The manual also includes app and design notes showing typical circuit techniques. Gordos Corp., 250 Glenwood Ave., Bloomfield, NJ 07003. **Circle No. 243**

**COMPUTER SECURITY** is the subject of this 114-pg. publication, first in a planned series of System Review Manuals. It is designed to enable the manager to assess threats likely to affect an installation. Throughout, the goal is to provide a methodology for gathering data so that the reader may organize himself to evaluate any specific system. Price is $10. AFIPS Press, 210 Summit Ave., Montvale, NJ 07645. **INQUIRE DIRECT.**

**IC'S.** A 44-pg. guide of monolithic analog CMOS switches and multiplexers describes 5 multiplexer families and 6 series of dual and quad switches. An applications section discusses protection schemes, terminology and applications in sample-hold amplifiers, data acquisition systems, filters, timing circuits, DAC's and ramp generators. Analog Devices, Inc., Box 280, Norwood, MA 02062. **Circle No. 244**

**FET-INPUT OP AMPS.** This 18-pg. document discusses the advantages of FET-input op amps over bipolar-driven ones. Also covered are techniques for op-amp offset nulling, input and offset current conditions and common-mode errors. The paper concludes with a design example of an op amp using a FET preamplifier as an input stage. Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, CA 95054. **Circle No. 245**


THERMOTRON
TIPS & TRENDS
ECA
Design & Selection "Environmental Cooling Air" And Distribution Systems

**ENVIRONMENTAL COOLING AIR** (ECA) and distribution systems are discussed in this 20-pg. booklet, "Tips & Trends." It covers general aspects of ECA design and selection, as well as the conditioning medium required, equipment sizes available, specification of "AGREE" reliability demonstration test chambers, and operation techniques. Thermotron Corp., Kollen Park Dr., Holland, MI 49423. **Circle No. 246**

**1974 AMT DESKTOP INDEX**, a guide to design articles in 8 top electronic periodicals, spans the last 3-1/2 yrs. and features over 5000 entries in some 250 categories. The index and a 6-mo. update cost $9 from AMT Desktop Index, Box 11275, Kansas City, KS 66111. **INQUIRE DIRECT.**

**TEST CHAMBERS.** An explanation of current regulations affecting the design and construction of chambers for hazardous applications is contained in Bulletin 746. Discussed against this background are the company's chambers designed to meet the recommendations of these regulatory codes. Blue M Engineering, 138th and Chatham Sts., Blue Island, IL 60406. **Circle No. 247**

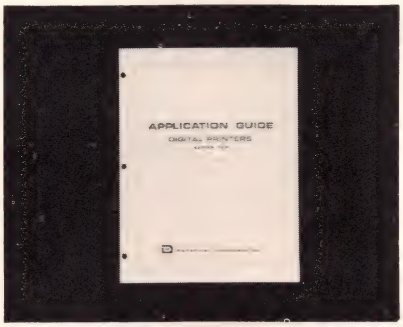
**PERIPHERALS.** This brochure presents a comprehensive run-down on a complete line of OEM products. Among the 13 products are input/output typewriters, alphanumeric strip printers, digital printers, tape punches, tape readers and cassette units. A concise description and photograph are included for each product. Facit-Addo, Inc., 501 Winsor Dr., Secaucus, NJ 07094 **Circle No. 248**

**SOLDER.** Complete technical data on a paste solder, Rheomet$^{R}$, developed for production assembly uses is included in a 4-pg. folder. Its mild, noncorrosive flux contains no halides. This new solder is designed for the manufacture of microcircuit hybrids, resistor networks and related products. Kester Solder Div., 4201 Wrightwood Ave., Chicago, IL 60639. **Circle No. 249**

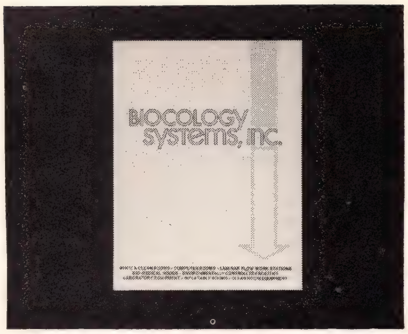
**JFET NOISE.** Audio freq. noise in JFET's is identified and characterized in this application note. Emphasis is placed on base device characteristics and operating point requirements. Siliconix, 2201 Laurelwood Rd., Santa Clara, CA 95054. **Circle No. 250**

**THICK-FILM RESISTORS.** The performance of 850-series resistor pastes on 96% alumina substrates from different suppliers is presented in Bulletin R-850-11. Materials giving 1, 10 and 100 kΩ/sq were processed on substrates from 5 different suppliers and the results evaluated. Thick Film Systems, Inc., 324 Palm Ave., Santa Barbara, CA 93101. **Circle No. 251**

**OPTICAL CHAR. READERS.** A 6-pg. brochure titled "OCR System for Outgoing Communication" contains sections that cover present system, OCR system, OCR system characteristics and financial justification. Photograph and diagrams show system applications, system components, controls and operational advantages. Datatype Corp., 1050 N.W. 163rd Dr., Miami, FL 33169. **Circle No. 252**



**DIGITAL PRINTERS.** Application Guide No. 7226 gives electrical and mechanical data required to apply high-speed digital printers. Included are field-tested circuit diagrams for operation of stepping motors and print solenoids. The guide also contains installation and blow-apart drawings. Datadyne Corp., Box 247, King of Prussia, PA 19406. **Circle No. 253**



**CLEAN-ROOM CATALOG** lists the various classifications for micro-contamination-control clean rooms. It gives specific detail as to how such classifications are reached and why they are necessary. Besides standard-sized rooms or portable units, the catalog describes special custom-built units that can be made to meet specific or unique needs. Biocology Systems, Inc., 19 Daniel St., Fairfield, NJ 07006. **Circle No. 254**

**FLAT RIBBON CABLE.** A series of 6 "How To" data sheets gives complete instructions on cutting, separating and stripping round-conductor ribbon cable for termination to pc boards, connectors and other circuitry components. Included are instructions for terminating bonded and laminated cable, bonded twisted pairs, laminated "3C" twisted pairs and "Double-Twist" laminated twisted pairs. Spectra-Strip Corp., 7100 Lampson Ave., Garden Grove, CA 92641. **Circle No. 255**

**μP REFERENCE MANUALS.** Two reference manuals for designers of microcomputer control and processing systems are available from Intel Corp. The books cover the design concepts, theory of operation, capabilities and applications of Intel's Intellec 4 and Intellec 8 microcomputer development systems. Available for $5 each. Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051. **INQUIRE DIRECT.**

**SOILAGE REMOVAL.** With just a flick of your wrist, this slide-rule reference calculator matches up the material or component used with the type of soilage involved. It immediately indicates the types of cleaning solutions and equipment recommended to solve your problem. $2. Branson Cleaning Equipment Co., Parrott Dr., Shelton, CT 06484. **INQUIRE DIRECT.**

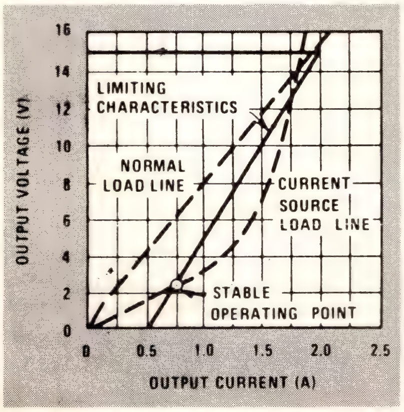
# signals and noise

## Power supply buyers—beware

Gentlemen:

I read the article touting the merits of foldback current-limiting for series voltage regulators (EDN, August 20, 1974) with great interest. Unfortunately, the drawbacks of the scheme were glossed over and one of the most important ones not mentioned. The particular one that I refer to involves the actual load characteristic that the supply will see in operation.

As the graph shows, when a load looks predominantly like a current source, the load line can intersect the foldback characteristic at a point where it will prevent a regulator from coming up to proper voltage level, even though an overload is not present. Fortunately, most solid-state circuitry have V-I power load lines that do not intersect with the characteristics of a simple foldback current-limiting design described by Mr. Haver in his article. However, the possibility cannot be ignored, and the regulator with foldback current-limiting must be designed with knowledge of the load. Buyers of power sources with this scheme of current-limiting should assure that their users systems' load lines do not result in a multiple intersection with that of the sources' V-I characteristics.



*Sincerely,*
*Ed Bloom*
*Intelcom Rad Tech*
*San Diego, CA 92138*

## One-up-personship???

Our July 5, 1974 article, "Get the most from your 4-function calculator" has generated lots of positive mail. One item has received more than its share of attention, the approximation of epsilon, especially after we published a letter in the August 20 Signals and Noise. There Mr. Zahalka suggests using 193/71 since it uses fewer keystrokes.

The author, Henry Morris, replies, "Accuracy considerably greater than his can be obtained by 878/323...It is nice to eliminate keystrokes whenever possible. My original answer of 2.7181818 is closest, in appearance, to 2.7182818, and was selected for that reason alone."

We'd like to thank both Robert Bagby of The Riley Company for his suggestion of a more rememberable number 302/111.1 or more accurate but less rememberable approximations of 33/12.14 or 25/9.197, and E. J. Pierce of Western Electric who suggests 2721/1001.

However, the following letter should put the entire situation to rest.—Ed.

## Touché

Dear Sir:

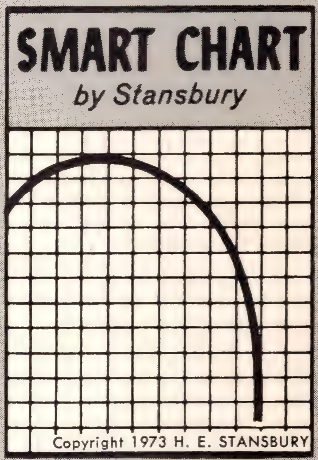
Here is some one-upmanship (or maybe one-up-personship) for you.

The 5 July 1974 edition of EDN had an article entitled "Get the most from your 4-function calculator." The approximation for epsilon given yields an error in the fifth significant digit.

Mr. L. B. Zahalka of GTE Satellite Corporation suggests in his letter to S & N published in 20 August 1974 the use of the approximation digit. If a person has only a five-digit machine, Mr. Zahalka's approximation gives the correct round-off for five significant figures. But it is in error for machines with greater than five digits.

I suggest writing the value of epsilon on a label and paste it on the calculator. Other constants can be written on the same label as well. e = 2.71828 18284 59045. Round off to match the number of significant digits on the calculator used. The value for a 5-digit calculator is 2.7183. It should be noted that it takes just as many keystrokes to enter this number as it does to enter 193/71. But how can one subtract epsilon from the displayed results in the calculator?

*Very truly yours,*
*Wm. A. Augros*
*FMC Corporation*
*Engineered Systems Division*
*Santa Clara, CA 95052*



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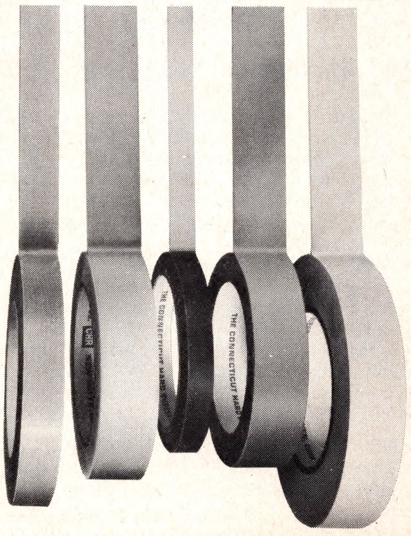

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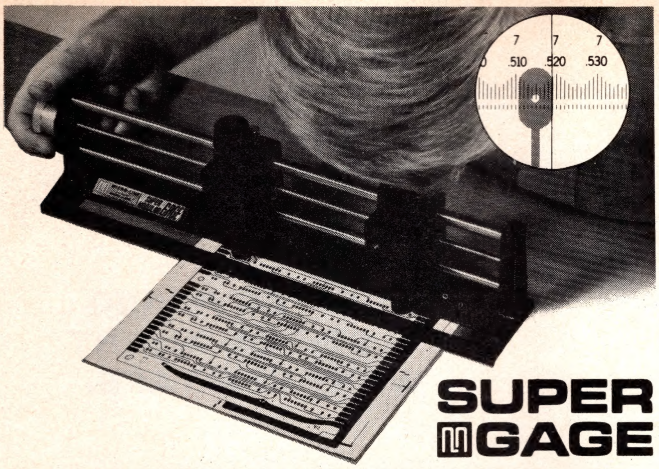

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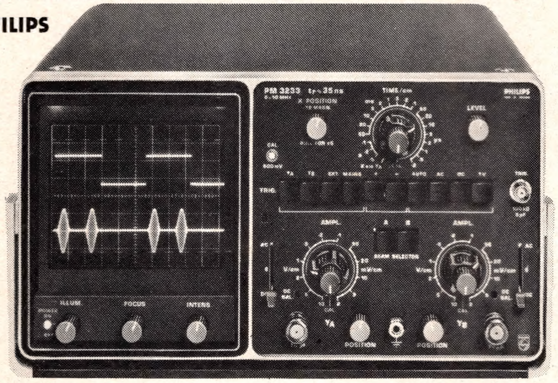

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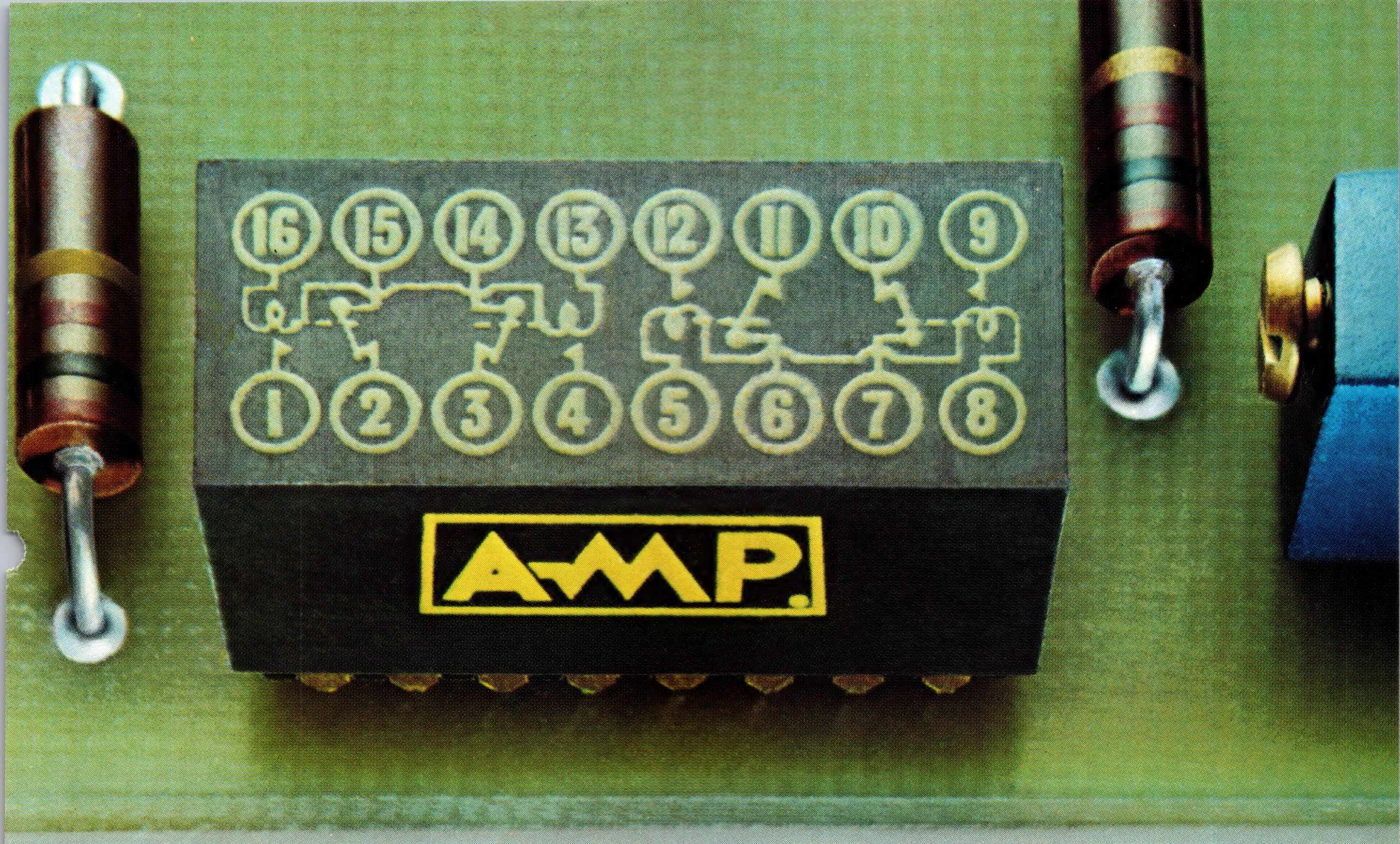

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